KILN DRYING HARDWOOD TIES—p. 165

Forest Products Journal

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Idea to Reality—FPRS New Home to be Dedicated June 22!—See p. 7-A.

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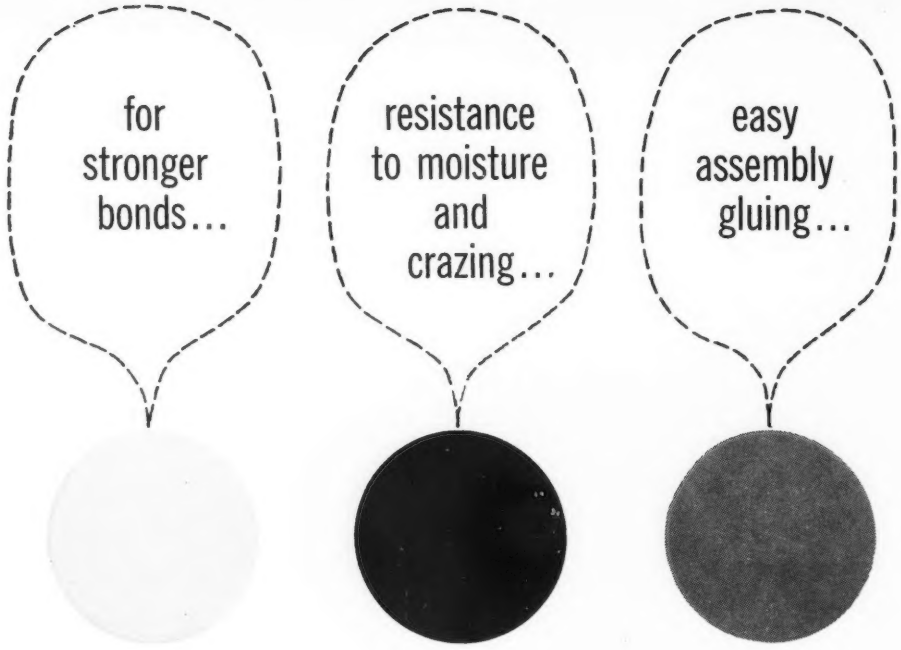

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FOREST PRODUCTS JOURNAL

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IMPORTANT FPRS DATES

June 22–27, 1958: Twelfth National Meeting, Madison, Wis.

Aug. 21–22, 1958: Great Lakes Section Meeting, Houghton, Mich.

Sept. 26–27, 1958: Inland Empire Section Meeting, Missoula, Mont.

Oct., 1958: Pacific Northwest Section Meeting, Vancouver, B. C.

Oct., 1958: Midwest Section Meeting

Oct. 28, 1958: Northeast Section Clinic Meeting, Jamestown, N. Y.

Oct. 30–31, 1958: Northeast Section Meeting, Lancaster, Pa.

Nov. 6–7, 1958: Carolinas–Chesapeake Annual Section Meeting, Charlotte, N. C.

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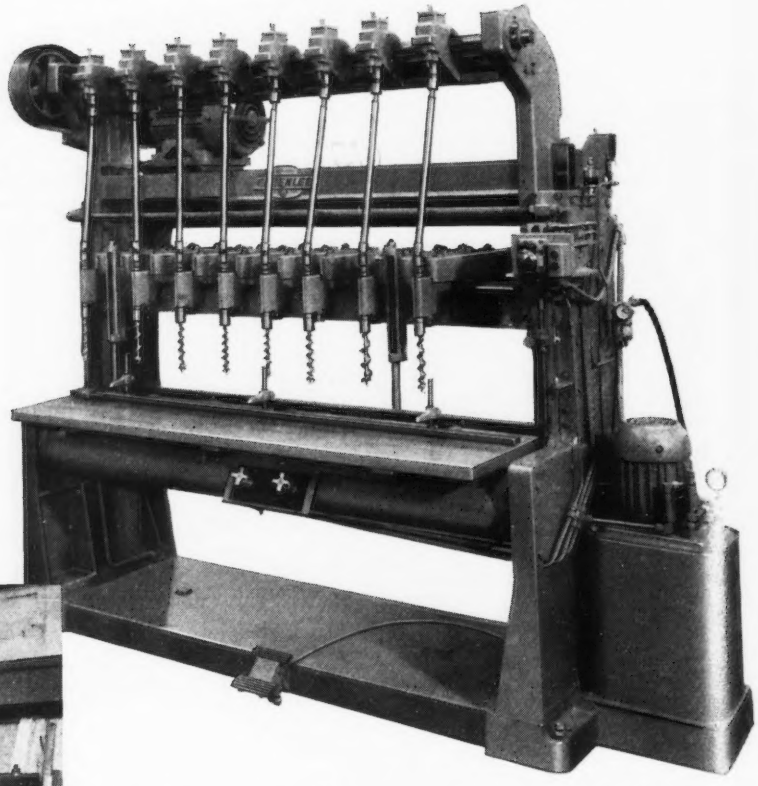

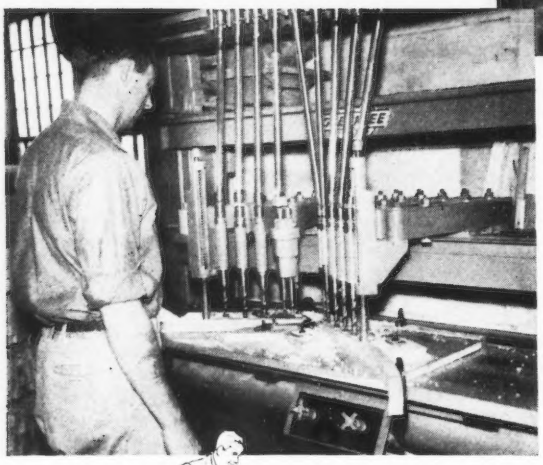

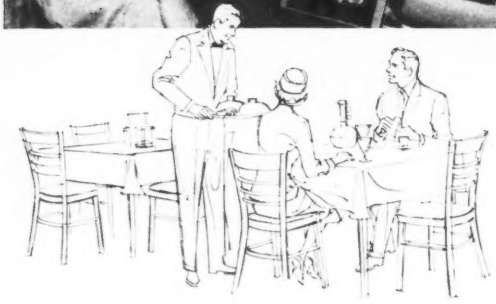

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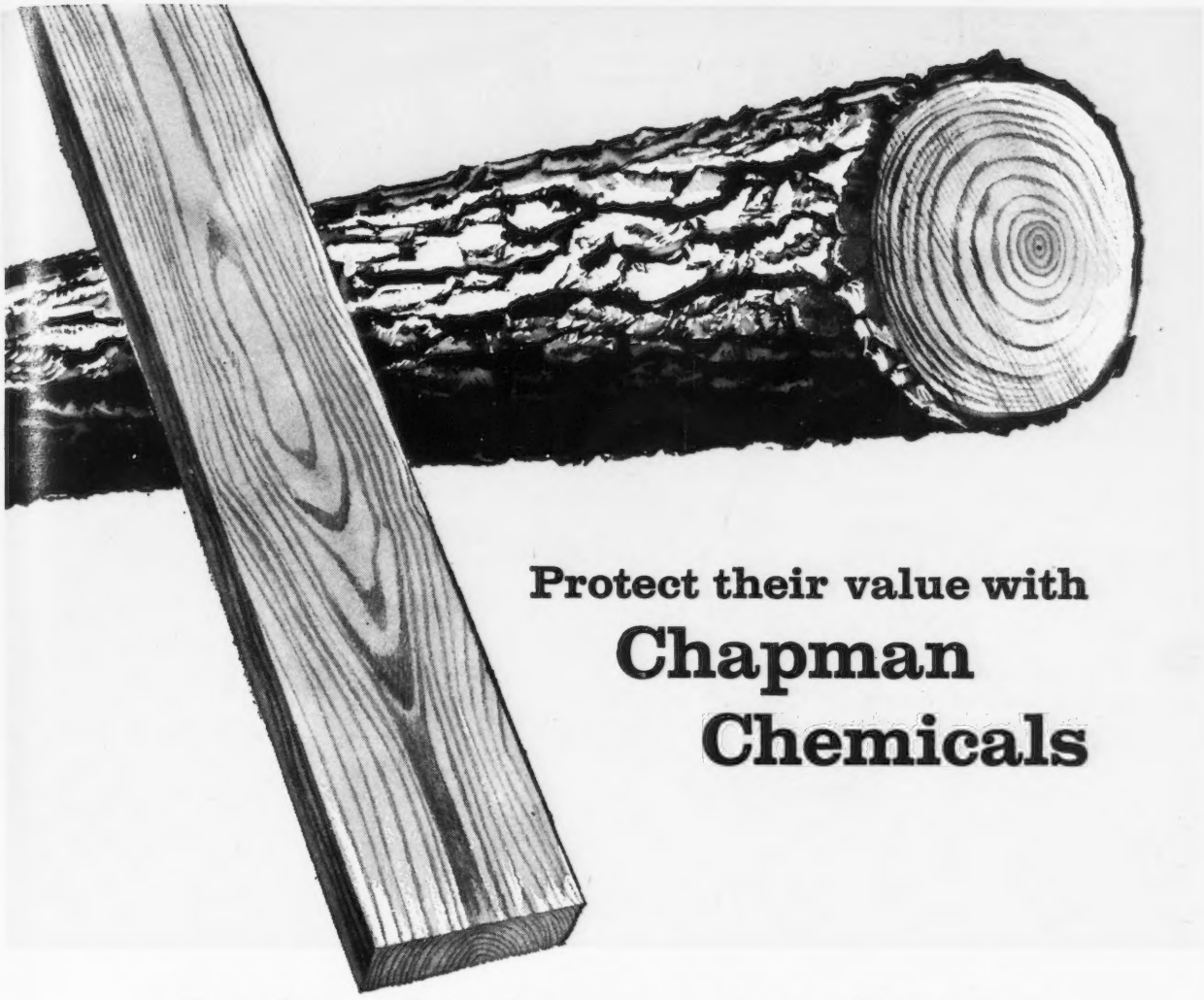

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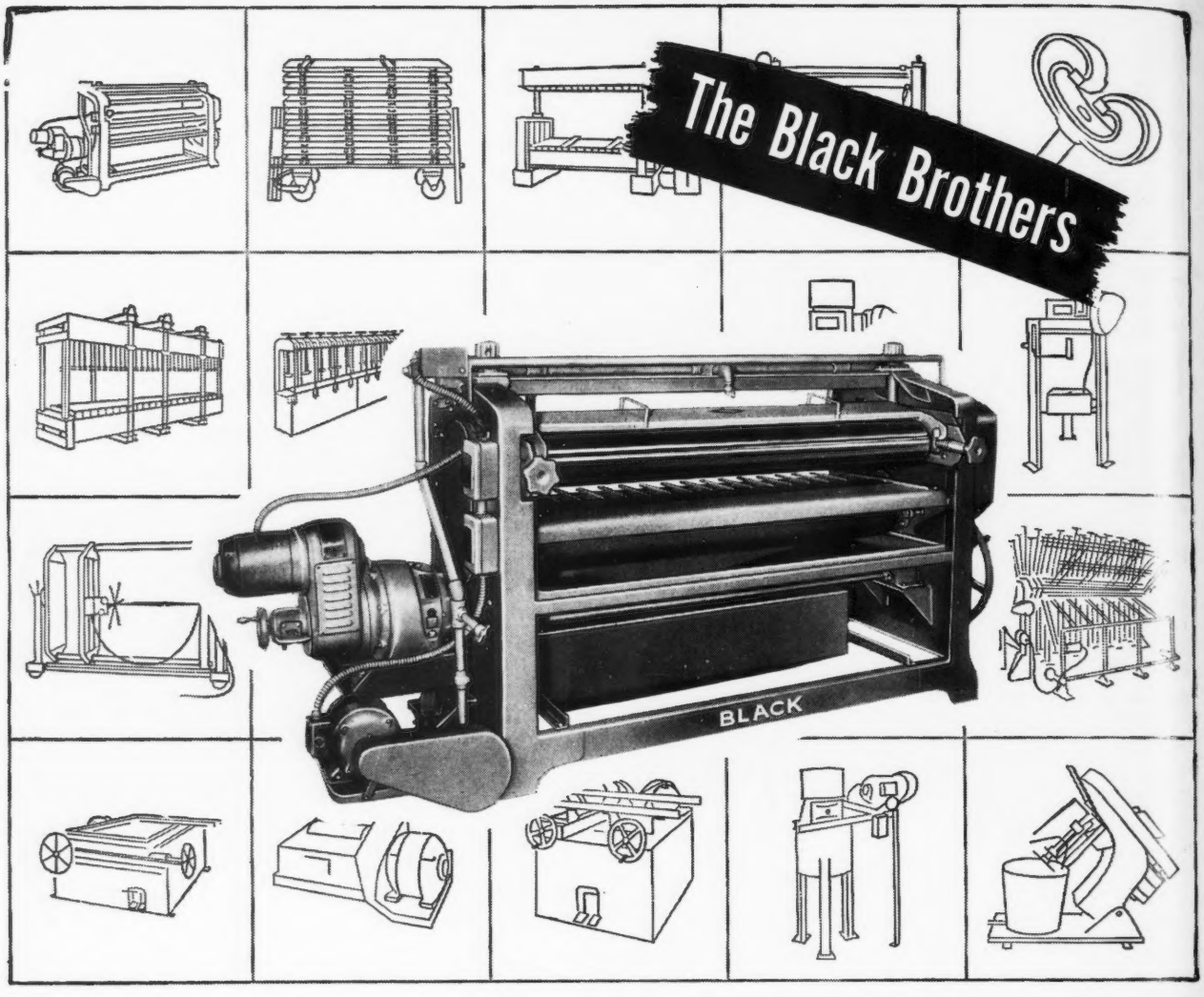

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FPRS NEWS-DIGEST

Volume VIII JUNE, 1958 Number 6

Last-Minute Roundup of Nat'l Meeting Events

Pre-registration and hotel reservation figures indicate a good turnout for the FPRS 12th National Meeting, starting June 22, at Madison, Wis., R. L. Hiller, Meeting General Chairman reported recently.

The comprehensive technical program and scheduled visits to the U. S. Forest Products Laboratory are the main events that will attract a representative cross-section from the forest products industries.

At the 6th meeting of the National Meeting Committee, May 20, last-minute details were completed for the meeting. The following is a chronological listing of events with time designations for each activity.

Sunday, June 22

12 *noon–4 p.m.*	Executive Board Meeting
1–4 p.m.	Wood Technologist's Meeting
5–6 p.m.	Dedication of the Executive Office Building
5:30–7 p.m.	Industry Education Committee Employment Committee Membership Committee
7–9 p.m.	Welcoming Reception—Hosts: Mid-West Section

Monday, June 23

7:30–9 a.m.	Authors Breakfasts
9–11 a.m.	Ladies get-acquainted coffee time
9 a.m.–12 noon	Session I—Wood Composition Board Session II—Wood Machining Session IIa—Logging
12:30–2 p.m.	Ladies Luncheon and Style Show Children's Lunch and Movies
2:30 p.m.	Ladies and Childrens Tour of Madison
2–5 p.m.	Session III—Keynote Session

HOTEL LORAINE, meeting headquarters.

7–9 p.m.	Publications Committee Closed Section Officers Meeting
7–10 p.m.	Tellers Committee

Tuesday, June 24

7:30–9 a.m.	Authors Breakfasts
9–11:30 a.m.	Session IV—Veneer & Plywood Session V—Wood Preservation Session VI—Industry-Education Childrens all-day supervised activities and tour of the zoo
11:30–12 noon	12th Annual Business Meeting
12 noon–2:15 p.m.	Official Luncheon
2:30 p.m.	Ladies tour of the U. S. Forest Products Laboratory
2:30–5 p.m.	Session VII—Helicopters in Logging Session VIII—Glues and Gluing Session IX—Quality Control
4 p.m.	Ladies Tea at the Governor's Mansion
6:30 p.m.	Past Presidents Dinner
7–9 p.m.	Closed Division Officers Meeting

Wednesday, June 25

7:30–9 a.m.	Authors Breakfasts
8–10 a.m.	Open Division Meetings: Lumber Manufacturing Wood Preservation Veneer & Plywood Quality Control Chemical Utilization Merchandising Packaging
10 a.m.–12 noon	Open Division Meetings: Wood Composition Board Logging Wood Drying Wood Machining Glues and Gluing Finishing
12 noon–1:45 p.m.	Executive Board—Section Officers Advisory Committee Luncheon
1:30 p.m.	Ladies and Childrens Boat tour of Lake Mendota
2–5 p.m.	Session X—Wood Composition Board Session XI—Wood Drying
1:15–4 p.m.	Session XII—Wood Finishing Session XIII—Chemical Utilization

(continued next page)

Welcome Reception Planned by Host Mid-West Section June 22, at Nat'l Meeting

Plans have been completed for the Welcoming Reception scheduled for Sunday, June 22, D. W. Bensend, Mid-West Section Chairman reports. The informal get-acquainted party, at which attendees will be guests of the Mid-West Section, will be held from 7 to 9 p.m. in the Crystal Ballroom of the Hotel Loraine.

According to Mr. Bensend, meeting participants, observers, and their families are urged to attend. A buffet of assorted cheeses, meats, and salads will be provided in addition to light beverages. A milk bar will be set up by one of the Wisconsin dairy associations for guests. Other Wisconsin firms are expected to provide foods for which they are well known.

AT THE 6th meeting of the National Meeting Committee May 20, were l. to r., T. Walter Noble, Food and Social Committee, L. J. Fitzpatrick, Paul Bunyan Hour, R. L. Hiller, General Chairman, and F. J. Rovsek, Executive Secretary.

PRESENT AT THE meeting held in the Hotel Loraine were Fred Strenge, Publicity, Mrs. Louise Dalton, secretary to Mr. Rovsek, W. C. Lewis, Laboratory consultation and alternate plant tours, J. C. Killebrew, U. S. Forest Products Laboratory tour, and Mrs. Sandra Parrini, editorial assistant.

Meeting Events

(continued)

6–7:15 p.m.	Paul Bunyan Social Hour
7:30 p.m.–Midnight	FPRS Party

Thursday, June 25

7:30–9 a.m.	Authors Breakfasts
9:30 a.m.	Ladies and Childrens trip to Blue Mounds, Cave of the Mounds and Little Norway.
9 a.m.–12 noon	Session XIV—Lumber Manufacturing Session XV—Chemical Utilization Session XVI—General Session
12 noon–1:30 p.m.	Executive Board—Division Officers Advisory Committee Luncheon
12:30 p.m.–5:15 p.m.	Tour of the U. S. Forest Products Laboratory

Friday, June 27

7:30–11:30 a.m.	Executive Board Breakfast Meeting
8 a.m.–5 p.m.	Consultation by appointment with individual staff members of the U. S. Forest Products Lab. Other Forest Products Open House Tours: Allis-Chalmers Co., Milwaukee, Wis. Harnishfeger Homes Inc., Port Washington, Wis. The Institute of Paper Chemistry, Appleton, Wis. Kimberly - Clark, Neenah, Wis. Marathon Div., Rothschild, Wis. Mosinee Paper Mills, Mosinee, Wis.
9 a.m. & 1:30 p.m. (Downtown Chicago)	Hammond Organ Co.—Chicago. Ill.

R. L. HILLER discusses the Ladies Program with Mrs. Fern Thompson, vice-chairman, and Mrs. Nancy Simeone, chairman of the Ladies Committee.

ALSO PRESENT were l. to r. W. L. Kluender, Budget and Finances, FPRS President Kaufert, and R. H. Hamre, Editor, FOREST PRODUCTS JOURNAL.

Award of Merit Citations to be Presented at FPRS Keynote Session, June 23

More than 30 nominations have been received for the Award of Merit Citations, officials of Hitchcock Publishing Co., sponsors of the Awards, have recently reported. Winners will be announced and receive their citations during the FPRS 12th National Meeting in Madison.

The awards are presented to organizations that have performed outstanding service or made a significant contribution to the promotion of wood and the utilization of wood during the year.

Judges for the annual event are: Mr. Sorenson, president, Hammond Organ Co.; M. G. Pendleton, executive secretary, National Hardwood Lumber Assoc.; Donald Davis, president, Aetna Plywood Co.; Herbert Joseph, vice-president, Handy Mfg. Co.; and C. W. Billingsley, Fuller, Ross & Smith.

Awards will be given to a producer of wood products with less than 100 employees; a producer with more than 100 employees; an association; a public institution or university; and a supplier to the wood products manufacturing industry. This latter group includes suppliers of material, equipment, and supplies.

Seven Schools to Hold Reunion Functions at Nat'l Meeting

Following the tradition of previous years, plans have been made by seven colleges and universities to hold reunion functions during the National Meeting, it was reported recently. Arrangements vary from breakfast to luncheon and dinner affairs. Times, type of gathering, and persons in charge are:

Yale University, Mon., June 23, 6:30 p.m., Hoffman House, R. L. Youngs.

University of Michigan, Tues., June 24, 8 a.m.

Pennsylvania State University, Wed., June 25, 7:30 a.m., Newell Norton.

New York College of Forestry, Wed., June 25, 8 a.m., H. B. Gatslick.

Michigan State University, Wed., June 25, 12 noon, A. J. Panshin.

North Carolina State College, Thurs., June 26, 8 a.m., Roy Carter.

Iowa State College, Thurs., June 26, 12 noon, Crandall Restaurant, Harold E. Wahlgren.

FPRS Ladies Invited for Tea at Governor's Mansion

Ladies at the National Meeting have been invited for tea at the Governor's Mansion by Mrs. Vernon Thomson on Tuesday, June 24, from 4 to 5 p.m., Nancy Simeone, Ladies Committee chairman reports.

New FPRS Building to be Dedicated June 22

FLOORING FOR THE Executive Office Building was furnished by the Arkansas Oak Flooring Co., Pine Bluff, Ark. Donated was 25/32 by 2¼ clear quartered red oak flooring. Estimated value of the donation is about $450.

SIXTEEN HUNDRED FEET of 1 by 6 clear heart vertical grain V-Joint redwood siding was contributed by the Pacific Lumber Co., Chicago, Ill. Estimated value of the donation is about $600.

Members, Meeting Participants Urged to Attend Ceremonies

Completion of the new FPRS Office Building is expected by June 22, the first day of the National Meeting, when Dedication Ceremonies will take place, the executive office reports.

The dedication will be held from 5 to 6 p.m. with industry, education, and public officials participating. FPRS President Kaufert will preside, and Madison Mayor Nestingen will deliver the welcome. Dr. J. A. Hall, Director, U. S. Forest Products Laboratory, will speak on the Society and the Laboratory, and the significance of the building will be described by W. Jeter Eason.

The ribbon cutting will be performed by Lt. Governor of Wisconsin Warren Knowles, and will be followed by exhibition of the building and the serving of refreshments.

Paneling Donors

The building, which was begun in December of 1957, has now entered the last stages of construction with interior finishing underway. Seven firms donated all the interior paneling for the building. Antique American Cherry paneling for the office of the Executive Secretary was donated by the Hardwood Corp. of America, Asheville, N. C. Bookmatched walnut plywood paneling for the editor's office was given by Algoma Division of U. S. Plywood Corp., Algoma, Wis. Roddis Plywood Co., Marshfield, Wis., donated the birch paneling for the central offices, and ash paneling was given by the J. J. Fitzpatrick Lumber Co. for the entranceway.

Rift Red Oak for the Conference Room was given by Nickey Bros., Memphis, Tenn. On the lower level, the mail room and lounge will be paneled by products donated by the Masonite Corp., Chicago, Ill. An auxiliary office will be paneled in walnut given by the Chester B. Stem Co., New Albany, Ind.

Another major contribution was made by the Paine Lumber Co. Ltd., Oshkosh, Wis. The firm is donating 1¾ inch REZO Doors for the Executive Office Building. Doors are being made to match the panelings in the various rooms.

Fund Drive Status

In recent communication with the national office, R. H. Berry, Chairman of the Building Fund Drive, stated that as of April 1, $50,000 of the $60,000 goal had been achieved in cash, pledges, and materials value. He went on to say that the Society will be able to meet all obligations upon completion of the building.

Regional Quotas Reached

As of April 1, the South West Region had attained 106.8 per cent of its goal in the drive. The South Central Region was next with a percentage of 100.6 of its goal. Percentage of goals attained by the other regions were: North East, 60.2 per cent; North Central, 86.0 per cent; North West, 82.5 per cent; and South East, 47.6 per cent.

Great Lakes Section Plans Meeting, August 21–22

A "real cool" meeting is planned by the Great Lakes Section for August 21–22, Meeting Chairman Hereford Garland reports. Lake Superior will provide the air conditioning and Michigan College of Mining and Technology, the facilities. "Wood Product Manufacture in the Wood Growing Area" will be the theme of the meeting. The college is located in Houghton, Upper Michigan.

Members of neighboring FPRS sections are invited to attend the meeting. It will offer the opportunity to combine a technical and economic program with a vacation trip, Mr. Garland reports. The new Mackinac Straits Bridge is expected to be an added attraction.

New Officers Elected by Inland Empire Section

New officers were elected by the Inland Empire Section at a meeting held April 16 in conjunction with the Northwest Wood Products Clinic, at Spokane, Wash. The new officers are: R. L. McNett, Biles-Coleman, chairman; C. M. Kreider, Brooks Scanlon, vice-chairman; and J. P. Howe, U. of Idaho, secretary-treasurer.

New trustees are: M. R. Knudson, J. Neils Lumber Co., and Syman Zachary, Browns Tie and Lumber Co. Holdover trustees are: L. E. O'Neil, Forest Products Co., and O. C. Sawyer, Peshastin Lumber and Box Co.

Tentative plans were made to hold a fall Section Meeting at Missoula, Montana on Sept. 26–27.

Fifty-Seven Firms to Date Will Host Paul Bunyan Social Hour

Thirteen more wood industry suppliers have signed up as sponsors of the Paul Bunyan Social Hour at the National Meeting, bringing the total up to 57 firms. Sponsoring firms will be hosts to registrants and their families at the Social Hour preceding the Official Party and Banquet, June 25, at the Maple Bluff Country Club. Refreshments will be served at the Social Hour.

The 57 sponsors of the annual event as of June 1 are:

Algoma Division, U. S. Plywood Corp., Algoma, Wis.
American Cyanamid Co., New York, N. Y.
American Mfg. Co., Tacoma, Wash.
American-Marietta Co., Seattle, Wash.
Arnold Dryer Co., Milwaukee, Wis.
The Bahnson Co., Winston-Salem, N. C.
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The Black Bros. Co., Inc., Mendota, Ill.
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The Carborundum Co., Niagara Falls, N. Y.
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Peter Cooper Corps., Gowanda, N. Y.
Decar Plastic Corp., Middleton, Wis.
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The Dow Chemical Co., Midland, Mich.
Fiberesin Plastics Co., Oconomowoc, Wis.
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Green Bay Paper & Pulp Co., Green Bay, Wis.
Edward Hines Lumber Co., Chicago, Ill.
Hitchcock Publishing Co., Wheaton, Ill.
Hooker Electrochemical Co., Durez Plastics Division, North Tonawanda, N. Y.
Hough Mfg. Corp., Janesville, Wis.
Industrial Woodworking, Cleworth Publ. Co., Cos Cob, Conn.
Kimberly-Clark Corp., Neenah, Wis.
Koppers Co., Inc., Pittsburgh, Pa.
The Lilly Co., High Point, N. C.
Masonite Corp., Chicago, Ill.
Mattison-Greenlee Service Corp., Rockford, Ill.
Mereen-Johnson Machine Co., Minneapolis, Minn.
Merritt-Solem Division, Solem Machine Co., Lockport, N. Y.
Moore Dry Kiln Co., Jacksonville, Fla.
D. J. Murray Mfg. Co., Wausau, Wis.
National Casein Co., Chicago, Ill.
National Lumber Mfrs. Assoc., Washington, D. C.
Nelsonite Chemical Products, Inc., Grand Rapids, Mich.
Nicholson Mfg. Co., Auburn, Wash.
Pacific Lumber Co., Chicago, Ill.
Paine Lumber Co., Oshkosh, Wis.
Perkins Glue Co., Lansdale, Pa.
Protection Products Mfg. Co., Kalamazoo, Mich.
Reichhold Chemicals Inc., Charlotte, N. C.
Rhinelander Paper Co., Rhinelander, Wis.
Sherwin-Williams Co., Chicago, Ill.
Simonds Saw & Steel Co., Leominster, Mass.
Soderhamn Machine Manufacturing Co., Talladega, Ala.
Solem Machine Co., Rockford, Ill.
Southern Screw Co., Statesville, N. C.
Standard Dry Kiln Co., Indianapolis, Ind.
Synvar Corp., Wilmington, Del.
United States Plywood Corp., New York, N. Y.
Weyerhaeuser Timber Co., Tacoma, Wash.
Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.
J. W. Wells Lumber Co., Menominee, Mich.

Thirteen Students Vie for 1958 Wood Awards

Thirteen students from seven colleges and universities have entered the 1958 Wood Award Competition, James S. Bethel, chairman, FPRS Industry-Education Division, and Jack F. Koellisch, Editor, Wood & Wood Products magazine, sponsor of the awards, have announced.

Two cash awards and certificates for the best papers will be presented at the FPRS 12th National Meeting in Madison. The first-place winner will receive $350 and will be invited to present his paper at the Meeting. The second place winner will receive $150.

Students from the following schools are entered in the contest: Iowa State College, Michigan State University, Oregon State College, Pennsylvania State University, State University of N. Y. College of Forestry, University of Minnesota, and Yale University School of Forestry.

Paper titles are: "Some Aspects of the Strain Behavior of Wood in Tension Parallel to the Grain"; "The Fundamentals of Water-Vapor Sorption by Wood"; "Effect of Tension Wood on Density, Toughness, and Endwise Compression of Cottonwood"; "A Method for Determining the Dry Weight and Volume of Green Aspen Boltwood"; "A Study of the Natural Durability of Diamond Willow Heartwood"; "An Electron Microscope Investigation of Pit Membrane Structure in Conifers and Hardwoods—Its Implications in the Seasoning and Preservation of Wood"; "The Strain Behavior of Wood Subjected to Repetitive Stressing in Tension Parallel to the Grain"; "Strength Retention in Woods Decayed to Small Weight Losses"; "The Effect of Particle Geometry and Resin Content on the Bending Strength of Oak Flake Board"; "The Strength of Second-Growth Douglas-fir in Tension Parallel to Grain; Stability of Bonded Electrical Resistance Strain Gages on Wood"; "Testing the Durability of Exterior Natural Finishes"; and "The Influence of Specific Gravity and Resin Content on the Properties of Particle Board Made with Species of Widely Different Specific Gravity".

European Exhibitors Invited to NAFM Fair, Aug. 24–27

European manufacturers of woodworking machinery and furniture fabrics have been invited to exhibit at the 4th Annual Supply, Equipment and Fabric Fair, Aug. 24–27, sponsored by the National Assoc. of Furniture Manufacturers, according to John M. Snow, executive vice president of the organization.

NAFM's Board of Directors voted to invite European participants because it was felt there were many important developments in these countries that are not readily available to the American furniture and woodworking industries.

"Because furniture sales have such a wide base in style and fashion, many of the European furniture fabrics are necessary to cover the entire market satisfactorily," Snow said. "A lot of progress can be made swiftly by furniture and woodworking executives who study new developments in these lines, over here. Only a very limited number can go abroad every year".

Kiln Drying Demonstration at F.P.L. Attended by 24

Twenty-four men attended the 82nd Kiln Drying Demonstration at the U. S. Forest Products Laboratory, Laboratory officials have reported. Fourteen of the enrollees, an unusually high percentage, were managerial personnel in the companies they represented. Among others attending the April 14–25 meeting were five dry kiln operators, two yard foremen, and three researchers. Discussed were basic principles of air and kiln drying of wood, and particular attention was given to improved methods.

BUSINESS NOTES

Lumber Products & Sales

Lumber production declined in February, according to NLMA estimates that place output at 2,327,000,000 board feet, six per cent below the previous month and 11 per cent below February 1957. Total softwood-hardwood output in the first two months of 1958 hit an eight-year low. Production of 4,803,000,000 feet was eight per cent below the year-age level. The board foot volume of retail lumber sales in February was down 16 per cent from the previous month and 22 per cent from February 1957.

(NLMA Lumber Letter, April 11, 19

Successful Wood Industries Conference Held by FPRS and ASME

More than 160 persons attended the March 30-April 1 Wood Industries Conference held at Syracuse, N. Y. "Applied Research in Wood Products" was the theme of the meeting, which was jointly sponsored by the FPRS Northeast and Eastern Canadian Sections and the Wood Industries Division of ASME.

At right, FPRS President Kaufert addresses remarks to the audience at the Official Banquet. Registration is shown at far right. From l. to r. are: Col. J. H. Jenkins, Canadian Forest Products Laboratories; Mrs. Harold Gatslick; Miss Betty Gallauresi; and Eric A. Anderson, Chairman, FPRS Northeast Section.

Col. Jenkins presented a paper entitled "A Canadian's Camera View of Russia's Forest Industries" at the Eastern Canadian technical session.

At the Official Banquet, l. to r. are: W. T. Nearn, Pennsylvania State U.; G. I. Vincent, chairman, Syracuse Section of ASME; T. J. Creal, Nat'l Furniture Mfgs. Assoc., who served as toastmaster; L. G. Brown, chairman, Wood Industries Division, ASME; G. B. Warren, vice-president, General Electric Co.; H. L. Shirley, Dean, State U. of N. Y. College of Forestry; and Col. J. H. Jenkins, Canadian Forest Products Laboratories.

The three-day meeting featured three technical sessions, each presented by one of the sponsoring organizations. In addition, two trouble-shooting panel discussions held simultaneously on Monday evening dealt with Wood Research and Gluing problems.

Highlight of the meeting was the trip to the Hugh P. Baker Laboratory at the State U. of N. Y. College of Forestry, where a demonstration of equipment and modern techniques in wood products research was given. The Laboratory was completed in 1957 at a cost of nearly four million dollars.

Northeastern Loggers Hold Successful Congress in April

More than 300 loggers, lumbermen, foresters, and equipment suppliers met at the Mark Twain Hotel, Elmira, N. Y., April 20–23 for the Fourth Northeastern Loggers' Congress. Four discussion sessions were held on "New Methods and Machinery", "Logging and Forest Management on Small Lots", "Logging Safety", and "The Small Sawmill Clinic". An exhibit of logging and sawmill equipment and supplies was held during the meeting.

Re-elected for another year in office were: William L. Faull, T. A. Hardes Lumber Co., Bradford, Pa., president; George Rodgers, Fisher Young Lumber Co., Titusville, Pa., secretary; and F. A. Reed, Northeastern Logger, Old Forge, N. Y., treasurer. Gerard Pesez, International Paper Co., Glens Falls, N. Y. was elected vice president for the coming year.

In other action, the Association voted to extend its territory into five additional states: Ohio, Illinois, Indiana, Michigan, and Wisconsin, so that it now includes a total of 17 states. A new Technical Division of the Association was approved to sponsor special subject matter conferences, like those previously held by the Northeastern Wood Utilization Council, which has since merged with the Loggers. A conference on "Better Utilization of Northeastern Beech" is planned for the autumn.

U. of Illinois Establishes 4-Year Forestry Curricula

Two 4-year professional curricula in forestry leading to the degree of Bachelor of Science in Forestry have recently been authorized for the University of Illinois, school officials report. Designed to prepare students for two areas, the curricula will cover Forest Production and Wood Technology and Utilization.

The new program replaces a two-year preforestry curriculum that has been offered for the past 20 years. The first work in the new curricula will be an eight weeks' summer forestry camp beginning July 14, and the first degrees will be awarded in June 1960.

FACULTY FOR THE new 4-year curricula are, top row l. to r. C. S. Walters; J. N. Spaeth, Dept. Head; J. J. Jokela; R. W. Lorenz; W. R. Boggess; Bottom row, l. to r., J. K. Guiher, K. R. Peterson, and C. E. Olson, Jr.

Society's Books Audited

The FPRS Audit Committee met with auditors in Madison the week of May 26, to examine the Society's 1957 finances, the executive office reports. Named to the committee by President Kaufert were H. O. Fleischer and John McMillen, U. S. Forest Products Laboratory, and Ralph Simeone, J. J. Fitzpatrick Lumber Co. The committee met with auditors Victor Hobert and Isidore Guthneck and the Executive Secretary.

FOREST PRODUCTS RESEARCH SOCIETY
BALANCE SHEET 12/31/57

Assets

Cash and Anchor Savings & Loan Shares	$11,340.14
Northwest Airlines Credit Card Deposit	425.00
Accounts Receivable	3,122.44
Executive Building Lot	10,070.60
Equipment Inventory	4,227.94
1958 National Meeting Advance	1,000.00
Postage Inventory	123.85
Supplies and Membership Material	2,793.63
Total Assets	$33,103.60

Liabilities

Accounts Payable	$ 141.57
Prepaid Membership Dues	1,878.50
Executive Office Building Contributions	4,162.73
Total Liabilities	$ 6,182.80
Net Worth	$26,620.80
Total Liabilities & Net Worth	$33,103.60

FOREST PRODUCTS RESEARCH SOCIETY OPERATING STATEMENT—C. Y. 1957
1/1/57–12/31/57

Cash January 1, 1957		$ 4,885.09	
Savings and Loan Shares		10,000.00	$ 14,885.09
Receipts:			
1960 Membership Dues	$ 15.00		
1959 Membership Dues	43.00		
1958 Membership Dues	1,820.50		
1957 Membership Dues	46,562.01		
1956 Membership Dues	226.00		
Dues Collected for Sections	5,484.00	54,150.51	
Publication Income		34,482.73	
Other Income		1,082.01	
Executive Office Bldg. Contributions		1,269.25	
1957 National Meeting		18,268.26	
1957 National Meeting Advance from 1956		1,000.00	
1957 National Meeting Funds of Convenience & Advance Payments Refunded		964.54	
1958 National Meeting		25.00	111,242.30
			$126,1[illegible]7.39
Expenditures:			
Central Office Expenses:			
Salaries	$34,035.68		
Supplies, Furniture, Equipment, FPL Agreement, Rent, Postage, Telephone, Telegraph, Internal Revenue, and Insurance	12,955.67		
Staff travel	2,936.06	49,927.41	
Executive Board Expense		195.98	
Real Estate Tax and Executive Office Bldg.		1,828.92	
Air Travel Deposit		425.00	
Publication Expense		32,457.63	
1957 National Meeting		15,774.49	
Return of 1957 National Meeting Funds of Convenience & Advance Payments		964.54	
Deposited with Mr. Berry for National Building Fund		2,423.79	
1958 National Meeting Advance		1,025.00	
Rocky Mountain Section Organization		50.00	
Membership Campaign		4,248.77	
Section Dues Remittances		5,484.00	114,805.53
Cash in Banks and Savings & Loan Shares 12/31/57			$ 11,[illegible]1.86

NAMES IN THE NEWS

The appointment of **Mr. Frank Hewyard, Jr.**, as the 1958 Colonel William B. Greeley Lecturer in Industrial Forestry at the University of Washington has been announced by Dean Gordon Marckworth of the College of Forestry. A series of three lectures will be given by Mr. Heyward, who is director of public relations, Gaylord Container Corp., a division of the Crown Zellerbach Corp.

Mr. Burdette Green has recently joined the firm of Elmendorf Research Inc. He was previously associated with the Fine Hardwoods Association.

J. W. LEWIS

R. H. BERRY

John W. Lewis, a civil engineering graduate of George Washington University, has joined the staff of the Timber Engineering, Co., Washington, D. C. He will work on new timber roof truss designs.

R. H. Berry, Scott Lumber Co., Burney, Calif., was recently appointed chairman of a special NLMA committee on education which is cooperating with FPRS Industry-Education Division in preparation of literature to attract young men to the wood products industries. Mr. Berry is a member of the FPRS Executive Board.

R. W. SHEPHERD

L. A. PATRONSKY

R. W. Shepherd announced recently that he will open and operate a consulting service in southern Indiana, with main consulting work to be on the angles of drying, bending and storage of lumber.

Two Research Managers have been named for the Timber Engineering Co., the NLMA laboratory announced recently. **L. A. Patronsky** was appointed western research manager, and **W. D. Eisenhauer**, eastern research manager. Both will be involved in research contact work with lumber manufacturers, wood-product manufacturers, and users. Mr. Patronsky was director of product development for Pack River Tree Farm Products, Spokane, Wash., and is a past FPRS chairman of the Wood Composition Board Division. Mr. Eisenhauer has been on the research staff of the laboratory for the past two years.

The appointment of **Vernon L. Parker** as manager of the Cutterhead and Knife Division of Yates-American Machine Co., Beloit, Wis., was announced recently by J. J. Gallagher, president of the firm.

American-Marietta Co. has announced the election of **Donald V. Redfern** as a vice-president. Redfern is general manager of A–M's Resin and Adhesive operations.

A. A. MARRA

J. I. ZERB[illegible]

Appointment of **Dr. Alan A. Marra** to the Central Research staff of the Simpson Timber Co. was announced recently by firm officials. Dr. Marra is currently on leav[illegible] of

absence from his post as Assoc. Prof. of Wood Technology at the U. of Michigan. Dr. Marra will establish the wood gluing and treating phase of Simpson's Seattle research and development program.

John I. Zerbe, wood technologist and former research professor for the Small Homes Council at the U. of Illinois, has joined the staff of the Technical Services Division of the National Lumber Manufacturers Assoc., according to a recent NLMA announcement.

E. L. Douglass, Augusta Hardwood Co., Augusta, Ga., was elected president of the Southern Hardwood Producers, Inc., at the association's annual meeting in New Orleans, March 13. Selected as vice-president for the coming year was **S. M. Nickey, Jr.,** Nickey Bros., Inc., Memphis, Tenn.

William P. Wheeler, forestry staff, Oregon State College, Corvallis, is the recipient of the St. Regis Paper Co. award of Fellowship in Forestry. Valued at $1,000, the Fellowship is given for one year. Mr. Wheeler plans to enter the N. Y. State University College of Forestry in September to continue his education toward a Doctorate in Forestry, with a major in Silviculture.

Elected president of the American Wood Preservers' Assoc., at the associations annual convention on April 14–16 in Los Angeles, was **Mr. P. B. Mayfield,** Barrett Division, Allied Chemical Corp. Manager of the Industrial Tar Product Sales department, Mr. Mayfield has been associated with the wood-preserving industry for 32 years.

H. H. Connelly, Supt., Core, Panel and Veneer Depts., Poinsett Lumber Co., Pickens, S. C., has been elected a Director of Cost and Production of the Southern Furniture Mfgs. Assoc. He will serve a three-year term.

NEW PUBLICATIONS

Care for Wooden Pallets can Control Maintenance Costs to You. Outlines briefly the major principles of prevention of damage to pallets and the proper care necessary to preserve pallet investment once damage has occurred. Available free from the Nat'l Wood Pallet Mfrs. Assoc., 609 Barr Bldg., Washington 6, D. C.

Effect of Environment on the Percentage of Summerwood and Specific Gravity of Slash Pine. P. R. Larson. Available at a charge from the Yale University School of Forestry on request of bulletin No. 63. New Haven, Conn.

CORRECTION

The dramatic superiority of combustible wood over non-combustible steel in the heat of an intense fire is shown in this photo of a Frankfort, N. Y. Casein Plant. In the April issue of the JOURNAL (page 32-A), this photo was erroneously credited to AITC. As many readers have recognized, this is a Bordon Chemical Co. photo that was well publicized in their advertising.

Can "Native" Lumber in Colorado Be Made More Acceptable on the Market? Robert W. Lange and Carl A. Newport. This study sought to reveal the various factors affecting the demand for native lumber through a survey of Colorado retail lumber dealers. General Series Paper No. 661. Available from the Colorado Agricultural Experiment Station, Fort Collins, Colo.

Indiana's Forest Resources and Industries. O. K. Hutchison. Presents results of a forest survey which report present supply of standing timber, how fast it is being increased through growth, and how much it is being diminished by industrial and domestic uses, fire, insects, diseases, and other causes. Available from Superintendent of Documents, Washington, D. C., 35 cents.

Performance of Bonded Wire Strain Gages of Wood. W. G. Youngquist. Gives the results of tests with a gage that measures the strain of wood under test. Report No. 2087.

Some Machining Properties of Nine Liberian Hardwoods. E. M. Davis. Quality tests were made on several of the hardwoods of Liberia. The paper reports that the best Liberian hardwoods machined were about on a par with the native hardwoods tested. Report No. 2093.

Index of Selected Journal Articles Pertaining to the Lumber Industry. W. I. West. A compilation of selected articles reflecting significant developments in the lumber industry as of December 1956 and emphasizing the last six to seven years. Published by Oregon State College Cooperative Assoc., Corvallis, Ore.

Proceedings of the Third Northeastern Wood Preservation Conference. Papers presented at the conference at New Haven, Conn., Nov. 1955. Available for $3.00 from the Northeastern Wood Utilization Council, P. O. Box 1577, New Haven 6, Conn.

Charcoal from Portable Kilns and Fixed Installations. A study of European Practices concerning charcoal. Available from the Food and Agriculture Organization of the U. N., Forestry Division, Rome, Italy.

Bending Solid Wood to Form. E. C. Peck. A handbook based on results of research on wood bending and related information as developed at the U. S. Forest Products Laboratory, other laboratories, investigations at furniture factories, ship and boat yards, and others engaged in commercial wood bending. Available for 15¢ from the Superintendent of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

Lumber Industry Facts 1957. A 48-page (revised) handbook containing more than 10,000 facts and figures on forest resources, lumber production, consumption, stocks and shipments, lumber industry employment, and wood exports-imports. Available free of charge from the National Lumber Manufacturers Association, 1319 18th Street N. W., Washington 6, D. C.

Defect in Piedmont Hardwoods. Reasons for the decline of quality of Piedmont hardwoods are examined. Research Note No. 115, available from the Southeastern Forest Exp. Sta., Asheville, N. C.

A "Modified Doyle" Rule-of-Thumb for Estimating Board-Feet in Small Logs. Walter C. Anderson. Research Note No. 116, available from the Southeastern Forest Experiment Station, Asheville, N. C.

Recommended Revision of Commercial Standard CS171–50, Hardwood Veneered Doors. Principal changes are new bondage requirements and tests, a new warpage test, new types of core construction, new grading requirements and grade markings, and the addition of hardboard- and plastic-faced flush doors. The revisions and consolidations were proposed by the National Woodwork Manufacturers Assoc., Inc. Limited copies of the Recommended Revision, TS–5383, Hardwood Veneered Doors, available on request from the Commodity Standards Division, U. S. Dept. of Commerce, Washington 25, D. C.

Pinholes in Logs and Lumber. F. C. Francia. Discusses the economic significance, biology, and control of the insects that cause pinholes. A Reprint from the Lumberman (Philippines). Available from the Forest Products Research Institute, College, Laguna, Philippines.

Wood Particle Board. Discusses economic, research, and testing factors connected with particle board production, with emphasis on current practises in the industry. Available from Reichhold Chemicals, Inc., RCI Building, White Plains, N. Y.

Economics of Barking and Chip Production. G. E. Bell. A Report based on sawmills in Eastern Canada. Reprint from Unasylva. Available from the Forest Products Laboratories of Canada, Ottawa, Ont., Canada.

The following publications are available free of charge from the U. S. Forest Products Laboratory, North Walnut Street, Madison, Wis.

List of Publications July 1 to December 31, 1957.

List of Publications on Glue, Glued Products, and Veneer. Report No. 513.

List of Publications on Box and Crate Construction and Packaging Data. Report No. 791.

List of Publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components. Revised list as of Feb. 1958.

List of Publications on Fungus Defects in Forest Products and Decay in Trees. Report No. 508.

Special Considerations Affecting Improvements in the Cold Soda Pulping Process. K. J. Brown. Results of the application of the cold soda process to several hardwoods. Done in order to determine the effect of certain variables on liquor penetration, pulp opacity, and color. Report No. 2101.

Sulphite Pulping of Engelmann Spruce. E. L. Keller. Revised Dec. 1957. Reported here is work which provides information on pulps that have been evaluated by more modern methods than in the original survey used. Report No. 1408.

Comparison of Wood Preservatives in Mississippi Post Study. 1958 Progress Report. J. O. Blew, Jr., and J. W. Kulp. Contains the latest results of continuing tests on the service life of posts treated with different kinds of preservatives. Report No. 1757.

Applying Forest Tree Improvement Practices in the Lake States: Production of Quality Wood. H. L. Mitchell. This report discusses why production of high-quality trees is desirable. Report No. 2103.

Mechanical Properties of Coulter Pine from California. A. W. Dohr. Results of tests of Coulter pine tested at the Laboratory. Report No. 2102.

A Fundamental Investigation of Adhesion. II. Method for Measuring Shrinkage Stress in Restrained Gelatin Films. R. C. Weatherwax, B. Coleman, and H. Tarkow. Reprint from the Journal of Polymer Science.

EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Positions Offered

E–309—Large British firm with timber concessions in the British Crown Colony of North Borneo, exporting both sawn timber and logs, requires experienced sawmill manager to supervise two modern mills. Operation is located in the city of Sandakan. Housing is furnished, paid home leave every two years, education allowance for children, retirement benefits. Reply stating age, experience, salary requirements. All replies confidential. (June)

E–312—Superintendent or plant manager needed with experience in hardwood dimension manufacturing including mouldings and interior trim. Opportunity to acquire an interest in a 39-year-old concern. Northern location. (July)

Employment Wanted

No. 468—Position desired in wood products industry. Holds BS in Forest Utilization. Army duty terminates July, 1958. Prefers Colorado, California, or Pacific Northwest location. (June)

No. 469—Position in research or product development desired. Holds degree in wood utilization from Michigan State University. Prefers Northeast or Mid-West location. (June)

No. 470—Position desired in buying, selling, or production aspect of a wood products organization. Previous experience includes timber cruising, marking, surveying, logging, and nine months of government research in log and tree grading. Holds BS in Forestry from West Virginia University. Presently attending John W. McClure Inspection Training School of NHLA. Available mid-July. (June)

No. 472—Research, teaching or production position desired. Holds BS in general forestry and will complete work on a masters degree in wood utilization in August from a major school. Has some research experience in both forestry and wood utilization. Northern location preferred. (July)

No. 473—Production or industrial engineering position desired. Holds BS in wood utilization from N. Y. State College of Forestry. Experienced as an industrial engineer and time standards analyzer in a cabinet plant. Prefers Northeast location. (July)

No. 474—Position desired with firm producing laminated structures, plywood and similar products. Holds BS in Forestry with Wood Utilization option. Now serving as a Naval Officer and will be available for work in September. North-Central or Northwest-Central location preferred. (July)

No. 475—Plant position desired. Holds a BS in Forestry and has five years experience in wood preserving industry. Prefers northeast or North Central location. (July)

No. 476—Executive position in production or development desired. Is a F.C.I.C. technologist. Has 20 years experience in wood products, plastics to wood, resin and adhesive manufacture, particle board and wood finishes. Will locate anywhere in Canada. (July)

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L. J. Carr & Co., Sacramento
High Sierra Pine Mills, Inc., Oroville
Ivory Pine Co., Dinuba
Scott Lumber Co., Inc., Burney
Ralph L. Smith Lumber Co., Anderson
Tartar, Webster & Johnson, Stockton

ILLINOIS
The Dean Company, Chicago
General Electric, Ill. Cabinet Plant, Rockford
Greenlee Tool Co., Rockford
Edward Hines Lumber Co., Chicago
Johnson & Carlson, Chicago
Masonite Corp., Chicago
Mattison Machine Works, Rockford
Sherwin-Williams Co., Chicago

INDIANA
The Dunbar Furniture Mfg. Co., Berne
National Homes Corp., Lafayette

KENTUCKY
Deluxe Saw & Tool Company, Louisville

MAINE
Moose Head Mfg. Co., Monson

MARYLAND
J. I. Wells, Salisbury

MASSACHUSETTS
Atlas Plywood Corp., Boston
Draper Corp., Hopedale
Heywood-Wakefield Co., Gardner
A. G. Spalding & Bros., Inc., Chicopee

MICHIGAN
Armstrong Machine Works, Three Rivers
Baker Furniture, Inc., Grand Rapids
The Dow Chemical Co., Midland
Everett Piano Co., South Haven

MINNESOTA
Mereen-Johnson Machine Co., Minneapoli
Minnesota Mining and Mfg. Co., St. Paul
Rilco Laminated Products, Inc., St. Paul
Wabash Screen Door Co., Minneapolis

MISSISSIPPI
Richton Tie and Timber Co., Richton

MISSOURI
Monsanto Chemical Co., St. Louis

MONTANA
Intermountain Lumber Co., Missoula

NEVADA
Vaughn Millwork Co., Reno

NEW JERSEY
National Adhesives, Plainfield
Western Electric Co., Kearny

NEW YORK
American Defibrator, Inc., New York
Behr-Manning Corp., Troy, N. Y.
Borden Co., New York
Peter Cooper Corps., Gowanda
The New Jersey Industries, Inc., New rk
Oval Wood Dish Corp., Tupper Lake
Pierce & Stevens Chemical Corp., B lo
Reichhold Chemicals, Inc., White Plains
United States Plywood Corp., Brewster
The Upson Co., Lockport

OHIO
American Machine & Foundry Co., Shelb
The Baldwin Piano Co., Cincinnati
Coe Manufacturing Company, Painesville
The Kirk & Blum Mfg. Co., Cincinnati

OREGON
Brooks-Scanlon, Inc., Bend
Cascades Plywood Corporation, Lebanon
Conroy Publishing Corp., Portland
Forest Fiber Products Co., Forest Grove
Mater Engineering, Corvallis
J. Neils Lumber Co., Portland
Oregon Lumber Co., Baker
West Coast Lumberman's Assn., Portland

PENNSYLVANIA
Kennametal, Inc., Latrobe
Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
United States Steel Homes, Inc., Harrisburg
Wood Metals Industries, Inc., Kreamer

SOUTH CAROLINA
Lightsey Brothers, Miley
Poinsett Lumber & Mfg. Co., Pickens

TENNESSEE
E. L. Bruce Co., Memphis
Chapman Chemical Company, Memphis
Memphis Hardwood Flooring Co., Mempl
Nickey Bros., Inc., Memphis

TEXAS
Wm. Cameron & Co., Inc., Waco
Kirby Lumber Corporation, Houston
Love Wood Products of Texas, Diboll
Southern Pine Lumber Co., Diboll

VERMONT
Beecher Falls Mfg. Corp., Beecher Falls

WASHINGTON
American Marietta Co., Seattle
Biles Coleman Lumber Co., Omak
Cascade Lumber Co., Yakima
Columbia Plywood Co., Inc., Seattle
Chelan Box & Mfg. Co., Chelan
Diamond Match Co., Spokane
Douglas Fir Plywood Association, Tacom
International Paper Co., Long-Bell Div n.
Longview
Simpson Logging Co., Shelton
Sumner Iron Works, Everett
Weyerhaeuser Timber Co., Tacoma

WISCONSIN
Harnischfeger Corp., Port Washington
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh

CANADA
B. C. Forest Products, Ltd., Vancouver
British Columbia Lbr. Mfrs. Assn., Vanc r
Canadian Forest Products Limited, New V minster, B. C.
Dominion Electrohome Industries, Kitchener, Ont.
Knight Mfg. & Lbr. Co., Ltd., Meaford,
MacMillan & Bloedel Ltd., Nanaimo, B.

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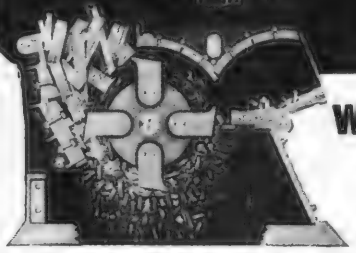
Typical automatic installation in many plants. All wood scrap is conveyed to the hog, then chips are blown to fuel bin. In some installations, chips are blown to a stoker which feeds them into boiler or furnace; in other cases, chips are blown directly into fire box



Cross section of "No-Nife" Hog showing how fast-moving chisel-edge hammer reduces wood by impact until properly sized to pass through grates in bottom of hog.

WILLIAMS "No-Nife" HOGS

When reduced to chips in a "No-Nife" Hog, wood scrap is 100% combustible—the cheapest of any fuel for producing heat and power. Money-wasting unhogged wood refuse won't burn evenly, restricts air flow, smothers the fire, causes excessive smoke and soot.

By hogging, handling costs are also reduced up to 75%. One man can handle as much tonnage in chip form as three men can handle in long lengths, awkward and odd-shaped pieces. In most installations, labor savings alone pays for a "No-Nife" Hog in a few months.

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CRUSHERS GRINDERS SHREDDERS
OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD

FPRS Forest Products Journal

Vol. VIII, No. 6
June, 1958

Kiln Drying of Southern Hardwood Crossties[1]

J. B. HUFFMAN

Associate Professor of Forest Products Technology,
University of Florida, Gainesville

Data gathered on 3,000 crossties indicate that it is feasible to kiln-dry hardwood crossties in preparation for preservative treatment. Four experimental charges of red and black gum preceded an industrial-size charge of gum plus red oak, elm, hickory, and beech. Seasoning defects were negligible in most cases, and subsequent pressure treatment with creosote was satisfactory.

FOR MORE THAN HALF A CENTURY, the art of kiln drying lumber has been practiced with increasing effectiveness and success, but only in rare instances has the process been employed to season large timbers. It is generally believed that poles, crossties, and structural timbers are too large to be kiln dried economically and without excessive degrade. There is, however, an increasing amount of evidence to support the premise that the process might be used with success, under present-day conditions, to season crossties. Based on this evidence, a cooperative project[2] was initiated in 1955 to determine the feasibility of employing kiln drying as a means of preparing green hardwood crossties for preservative treatment.

Segelken (10,11)[3] clearly demonstrated that green southern pine poles, kiln-dried for four days at 232° F. and 24 per cent relative humidity, were well conditioned for preservative treatment. He reported that seasoning checks were smaller than in poles that were air seasoned. In France, the Estrade process employs a kiln heated to 110° C. without humidity control to further dry air-seasoned spruce poles (7). Further demonstrations to the fact that accelerated methods can be used successfully to season crossties are Hudson's vapor-drying process (3, 4, 5) and Vaughan's controlled-air-seasoning method (12, 13). Red oak, red gum, and hickory can be vapor dried in about 12 hours, whereas red and black gum ties can be controlled-air-seasoned in 16 to 20 days.

The present-day policy of the railroads to reduce crosstie inventories and to procure ties during favorable business cycles has increased the need for faster seasoning methods. The fact that large inventories of crossties on air-seasoning yards tie up capital investments and real estate is another incentive for faster drying. Accelerated methods are also desirable due to the increased use of species that are susceptible to fungus attack during air seasoning.

Still another fact to be considered is that the high temperatures employed in kiln drying are more than enough to insure complete sterilization (1) of the crossties, and thus reduce the possibility of decay in untreated tie centers after relatively short periods of service. The current high cost of labor and materials dictates that every effort be made toward the production of crossties with maximum durability. The newly adopted policy of many railroads to incise their crossties may well reduce the amount of objectionable checking that might occur in kiln-drying crossties (2). Finally, many of the preservative-treating operations have dry kilns that are not being used to capacity, and these could be utilized for drying crossties with a minimum outlay of capital.

Scope and Objectives

The specific objectives of this investigation were, 1) to obtain data on moisture content, moisture distribution, rate of water removal, and degrade when accelerated kiln schedules are employed to dry crossties, 2) to determine the effects of species and heartwood content in relation to the above items, 3) to determine if kiln-dried ties react satisfactorily to preservative treatment, and 4) to collect and analyze cost data on the process involved.

A laboratory-kiln study and a commercial-trial study were performed over a period of two years in an attempt to attain these objectives. The first phase of the work involved the drying of four kiln charges consisting of red gum (*Liquidambar styraciflua* L.) and black gum (*Nyssa* sp.) crossties in a conventional type, cross-circulation dry kiln measuring 12 by 12 by 20 feet. Each charge contained 252 ties, and different kiln schedules were used for drying. After drying and subsequent pressure treatment with creosote, the ties were installed in track for future observation. A detailed report describing this phase of the work has been published (6); however, a brief summary of the results is presented below.

The final phase of the investigation, the commercial trial, involved the drying of a single charge of 2016 crossties in an industrial-size kiln. The compilation of evidence to substantiate the laboratory findings and the determination of costs for kiln drying ties on a commercial scale were the objects of this phase of the work. This fifth charge also presented an opportunity to test the reaction of several other species of ties when subjected to the kiln-drying treatment. The charge consisted of 1875 red and black gum (*Liquidambar styraciflua* L. and *Nyssa* sp.), 54 red oak (*Quercus* sp.), 54 hickory (*Carya* sp.) 22 beech (*Fagus grandifolia* Ehrh.) and 11 elm (*Ulmus* sp.) ties. This phase of the study will receive primary attention in this paper.

Results of Laboratory Kiln Study

Information collected during the laboratory phase of the investigation led to the conclusion that it was technically feasible to kiln-dry gum crossties to a treatable moisture content in three days without objectionable sea-

[1] Presented at Session IX, Wood Drying, of the F.P.R.S. Eleventh National Meeting, held June 23–28, in Buffalo, New York.

[2] Cooperators were Koppers Co., Inc.; Moore Dry Kiln Co.; Atlantic Coast Line Railroad Co.; Seaboard Air Line Railroad Co.; and the School of Forestry, University of Florida.

[3] Numbers in parenthesis refer to the Literature Cited at the end of this paper.

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soning defects. Three of the four kiln schedules employed during this phase of the study are presented in Fig. 1. The 9-day schedule for Charge 2 is omitted because of its similarity to Charge 1.

In general, the surface checks occuring in the kiln-dried ties were shorter and narrower than those generally observed in air-seasoned ties. End checks extended into the kiln-dried ties for very short distances. Incising of the ties was considered to be an important factor in limiting the size of the checks. Slight collapse occurred frequently in red gum heartwood ties from Charges 1 and 2, but seldom appeared in the ties from Charges 3 and 4. General observation of the ties after installation in a track revealed that rapid kiln drying at high temperatures resulted in fewer seasoning defects than kiln drying at slower rates and lower temperatures. Of the 1000 ties seasoned in the laboratory kiln, not one required doweling or was rejected because of seasoning degrade.

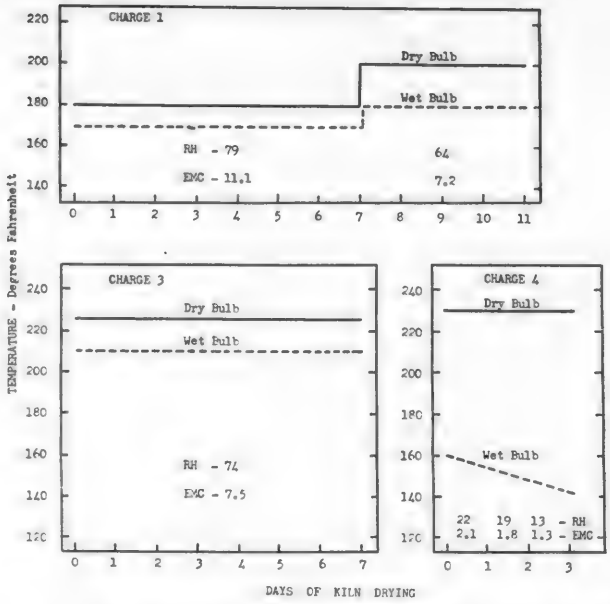

Fig. 1.—Three schedules used in kiln drying gum crossties during the laboratory study. Equilibrium moisture content and relative humidity are based on chart by R. Weylwerth (8).

The total weight of each charge was determined before and after kiln drying, and average water-loss values were calculated and are presented in the following table together with initial and kiln-dried moisture contents. Wide variation of moisture content among individual ties was observed; this variation combined with differences due to wood density, unintentional air-drying, kiln charge conposition, and other factors may be cause for some of the moisture content differences between the charges.

Subsequent pressure treatment of the kiln-dried ties with creosote resulted in retentions and penetrations that were equal to, if not better than, those which normally occur in air-seasoned ties. Several of the cooperators felt that the penetration was definitely better than that found in air-seasoned ties. Table I presents a summary of moisture content and creosote treating data for the 120 red and black gum crossties kiln dried in Charges 3 and 4.

Kiln Charge Number	1	2	3	4
Hours of Drying	264	216	168	72
Month Kiln Dried	Dec.	Jan.	July	Aug.
Water loss—lb. per tie	52.2	46.8	50.3	31.0
Water loss—lb. per cu. ft. per hr.	.056	.058	.080	.116
Initial moisture content[1]—%	106.5	102.4	87.5	71.1
Kiln-dried moisture content[1]—%	54.0	57.6	39.8	34.9
Initial moisture content[2]—%	74.6	94.8	87.5	74.5
Kiln-dried moisture content[2]—%	21.9	50.5	45.1	42.2

[1]Based on average specific gravity of red and black gum, 0.45.
[2]Determined from discs of six kiln samples by ovendry method.

Table 1.—MOISTURE CONTENT AND CREOSOTE TREATING DATA FOR 120 RED AND BLACK GUM CROSSTIES KILN DRIED IN CHARGES 3 AND 4[1]

Kiln charge 1	Species 2	Heartwood volume[2] per cent 3	Initial moisture content[3] per cent 4	Kiln-dried moisture content[3] Per cent 5	Kiln-dried moisture content[3] Standard deviation 6	Creosote retentions Lb. per cu ft 7	Creosote retentions Standard deviation 8	Creosote penetra-tions[3] inches 9
3	Black gum	0	58.7	26.0	3.1	9.03	0.78	2.3
	Black gum	10	78.6	41.5	10.3	7.97	.74	1.9
	Black gum	30	68.4	37.5	7.5	6.81	.90	1.5
3	Red gum	10	96.6	57.1	21.1	9.36	1.53	1.9
	Red gum	30	94.8	57.7	10.8	8.17	1.09	1.4
	Red gum	60	82.5	52.6	18.0	6.52	.67	1.5
	Averages		79.9	45.4		7.97		1.8
4	Black gum	0	48.6	27.8	7.5	9.62	.77	2.6
	Black gum	10	80.4	60.5	13.8	9.33	1.00	1.9
	Black gum	30	102.3	80.1	20.0	8.54	1.14	1.6
4	Red gum	10	82.4	57.8	17.2	10.56	1.10	2.1
	Red gum	30	89.8	63.3	14.7	9.40	.72	1.8
	Red gum	60	88.3	68.6	20.2	7.69	1.14	1.3
	Averages		82.0	59.7		9.19		1.9

[1]Values based on average of ten ties.
[2]Average of heartwood area observed on both ends of ties.
[3]Determined by increment borings into broad face of ties.

The Charge 4 schedule had definite advantages over the other schedules employed. The schedules used for Charges 1 and 2 produced satisfactory results, but the times required were considered too long. To maintain the relative humidity condition in Charge 3, an excessive amount of steam was consumed. With the Charge 4, schedule, moisture removal rates were rapid, sufficient drying was accomplished in a short period, seasoning defects were insignificant, retentions were greater and steam consumption was relatively less than for the other schedules.

Materials and Methods

The crossties for Charge 5, the commercial trial, were shipped out of southeast Alabama during the latter part of January, 1957. Supplied by the Atlantic Coast Line Railroad Company, the ties were sawn and incized before kiln drying, and were adzed, bored, and trimmed to a length of 9.0 feet after kiln drying. It was estimated that the ties had been cut 4 to 6 weeks before they were dried.

Kiln drying of the ties was accomplished in the Koppers Company dry kiln located at Gainesville, Florida. The double-track, cross-circulation Moore dry kiln was 135 feet long. The crossties were piled on kiln trucks as shown in Fig. 3; each tier of ties was supported by two 2 by 4-inch stickers. Approximate conditions existing within the kiln during Charge 5 are presented in Fig. 2. Steam-spray ties

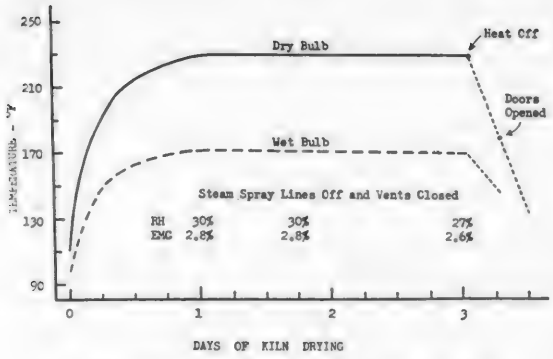

Fig. 2.—Approximate conditions existing within the industrial-size kiln during Charge 5.

Fig. 3.—Gum crossties stacked on kiln trucks before movement into kiln for drying.

and air vents remained closed during the course of drying.

To determine how the crossties reacted to kiln drying and subsequent pressure treatment, specific information was gathered on 154 selected crossties. Included in this number there were 11 ties in each of 14 species-heartwood volume groups; these groups are listed in the first two columns of Table 3. All of these ties had boxed hearts and were approximately seven by nine inches in cross-section.

During drying, the selected ties were placed in the bottom of five tiers of four kiln stacks in accordance with a stratified plan that had been used in the laboratory study; each tier contained one tie selected at random from each of the 14 species-heartwood categories. Ten ties from each category were later placed together in a test track, while the eleventh tie in each group was sectioned at the midpoint after kiln-drying to determine moisture content and moisture gradient. Initial moisture contents were determined by the ovendry method on increment borings taken at the midpoint of 14 sample ties representing the 14 species-heartwood groups. Kiln-dried moisture contents and moisture gradients for these 14 ties were determined by ovendrying two 1-inch, cross-sectional discs sawn from the center of each sample tie; the gradient discs were sawn into outer 1-inch, second 1-inch, and core sections.

Water-loss values and retentions of creosote for 140 special test ties were determined from individual tie weights and volumes before and after kiln drying and treating, respectively. Kiln-dried moisture contents for these ties were determined by ovendrying increment borings. Penetrations of creosote into the 140 crossties were ascertained from borings taken from the narrow faces of the ties.

The dimension (width and length) of the largest and most objectionable check observed on the adzed face of each special test tie was measured to

Table 2.—SUMMARY OF DATA ON PRESSURE TREATMENT OF KILN-DRIED CROSSTIES WITH 80/20 CREOSOTE COAL TAR SOLUTION

Charge number 1	Number of ties 2	Initial air psi 3	Treating pressure psi 4	Average treating temperature °F 5	Pressure period hrs. 6	Gross[1] absorption lb/cu ft 7	Net[1] retention lb/cu ft 8
199	527	78	190	199	5.0	14.51	9.23
202	526	85	190	200	5.5	11.59	5.39
202R[2]	526	78	191	202	2.0	10.06	3.66
211[3]	443	75	195	202	4.5	11.94	7.84
213	506	80	198	198	5.0	10.36	7.71

[1] Based on measuring-tank readings.
[2] Retreatment required to obtain desired retention.
[3] Charge containing special test ties.

Table 3.—MOISTURE RELATIONSHIPS AND DIMENSIONS OF CHECKS IN 140 CROSSTIES KILN DRIED IN CHARGE 5[1]

Species 1	Heartwood volume per cent 2	Initial tie weights lb. 3	Water loss: Per tie lb. 4	Water loss: Average rate lb/cu ft/hr 5	Kiln-dried tie weights lb/cu ft 6	Kiln-dried moisture contents[2] per cent 7	Average dimensions of most objectionable check[3]: Width in. 8	Average dimensions of most objectionable check[3]: Length in. 9	Dimensions of widest check observed[3]: Width in. 10	Dimensions of widest check observed[3]: Length in. 11
Black gum	0	249.6	59.3	0.206	47.6	42.5	0.08	6.5	0.13	10
Black gum	10	260.8	63.7	.210	46.7	49.7	.10	6.2	.19	10
Black gum	30	248.0	57.5	.190	46.3	58.1	.13	8.2	.19	18
Red gum	10	255.6	63.9	.218	47.1	69.7	.15	6.6	.38	7
Red gum	30	246.6	57.2	.198	47.2	77.3	.16	7.5	.25	6
Red gum	60	237.5	50.8	.177	46.9	70.6	.27	9.4	.75	18
Red gum	90	230.1	52.1	.190	46.7	58.6	.20	6.3	.38	4
Elm	100	244.6	56.3	.195	47.0	48.3	.22	9.4	.50	34
Hickory	0	279.9	45.7	.164	60.4	31.7	.26	8.4	.50	7
Hickory	30	275.0	53.9	.152	54.9	46.8	.24	12.1	.38	20
Beech	20	245.8	55.4	.196	48.4	39.2	.25	7.9	.50	12
Beech	50	256.3	56.3	.199	50.9	42.6	.20	8.7	.38	12
Red oak[4]	100	275.4	53.2	.188	56.4	60.7	.13	4.8	.19	6
Red oak[5]	100	271.6	51.9	.183	55.9	61.0	.27	7.1	.63	9
Overall Averages:		255.5	55.4	.190	50.2	54.1				

[1] All values excepting those in columns 10 and 11 are based on average of ten ties.
[2] Determined by the ovendry method on borings taken at midpoint on broad face of ties.
[3] Observations made on top face of ties.
[4] Southern red oak (Q. rubra L.) and related species.
[5] Water oak (Q. nigra L.) and laurel oak (Q. laurifolia Michx.)

evaluate the seriousness of this defect. This simple system of grading will later facilitate a study of how the checks increase or diminish in size during service life in the track. A pictorial record, in both color and black and white, was kept to permit further comparisons. A record was also kept on how many of the ties required doweling or were rejected because of seasoning defects.

It should be pointed out that the selection of two red oak groups for this study stemmed from the claim that water oak (*Q. nigra* L.) and laurel oak (*Q. laurifolia* Michx.) are more difficult to season and treat with satisfactory results than are southern red oak (*Q. rubra* L.) and related species. Separation of the ties into the two groups was based to a large extent on the experience and knowledge of the tie producer; reasonable confidence may be given to the validity of this separation but it cannot be guaranteed.

Because of special interest in how hickory and red oak ties might react to kiln drying, 32 additional ties of each species were kiln dried for observation.

Four treating charges were required to pressure treat the 2002 kiln-dried ties with creosote. Summary data for these charges are presented in Table 2. The ties on which special data were collected were treated in Charge No. 211. Because this charge contained a preponderance of gum ties and because gum ties were of principal concern in this study, no modification of the treating schedule was made to favor the hickory, oak, and beech ties. It was expected that these ties might receive sub-standard treatments.

Results and Discussion

The majority of the data collected during the commercial phase of this investigation are summarized in Tables 3, 4, and 5, and are depicted graphically in Fig. 4. Other findings relating to steam consumption, costs, and number of ties doweled are presented below. An exact, concise interpretation of the data is difficult to present because of the numerous factors involved, because of variations in the data, and because of differences of opinion as to what constitutes a satisfactory seasoning and treating job. The cooperators were in general agreement, however, that kiln drying of crossties on a commercial scale shows great promise of being a successful practice.

Moisture Removed by Kiln Drying: Water-loss values presented in Table 3, columns 4 and 5, show that the 140 test ties lost an average of 55.4 pounds of water per tie at the average rate of 0.190 pound per cubic foot per hour. Based on these figures, Charge 5 ties lost slightly less than two times as much water per tie, at almost twice the rate, as did the ties from Charge 4, even though the charges were dried according to the same schedule. This difference in water removed may possibly be explained by the fact that Charge 5 ties were relatively freshly cut and had greated initial moisture contents than Charge 4 ties; the later were processed during the summer while Charge 5 ties were processed during the winter. Other factors such as differences in species composition of the charges, inherent differences in the wood of the two charges, and differences in the ventilating characteristics of the two kilns employed, may also have been partly responsible.

The kiln-dried moisture contents for the 140 test ties are recorded in Table 5, column 3, and range from 31.7 per cent for sapwood hickory to 77.3 per cent for red gum with 30 per cent heartwood. These values, determined by borings taken at the midpoint of the ties, are considered to be higher than the true average moisture contents of the ties but were easily obtained and comparisons between different charges and species are possible. Standard deviations of the kiln-dried moisture contents are given in column 4. A more accurate but costly and limited measure of the kiln-dried moisture contents is presented in Table 4, column 4. These values, which were determined by ovendrying 1-inch discs cut from the center of 14 ties, ranged from 26.0 per cent for sapwood hickory and black gum to 69.8 per cent for red gum with 90 per cent heartwood. Of course, this method necessitated the destruction of the ties.

An insight as to how the moisture is distributed within the kiln-dried ties is provided by the moisture gradient data in Table 4, columns 5, 6, and 7. It is important to note that, for the majority of the 14 ties, the moisture

Table 4.—MOISTURE CONTENTS AND MOISTURE GRADIENTS IN FOURTEEN CROSSTIES KILN DRIED FOR 72 HOURS WITH DRY-BULB TEMPERATURE OF 230° F.

Species	Heartwood volume, per cent	Initial moisture content (boring) per cent	Kiln-dried moisture content[2] (1-inch disc) per cent	Moisture distribution[2] (1-inch discs)		
				Outer inch per cent	2nd inch per cent	Co per
1	2	3	4	5	6	
Black gum	0	47.5	26.0	8.1	31.6	4
Black gum	10	87.8	33.1	17.1	37.5	4
Black gum	30	108.4	57.5	28.9	80.1	8
Red gum	10	84.7	46.3	13.9	53.5	7
Red gum	30	79.5	45.1	18.1	53.2	7
Red gum	60	125.7	66.5	15.4	74.8	13
Red gum	90	152.0	69.8	23.9	81.8	13
Elm	100	76.2	32.2	10.1	39.2	5
Hickory	0	53.5	26.0	13.8	27.3	4
Hickory	30	53.9	29.0	10.4	35.4	5
Beech	20	83.3	42.0	20.0	51.0	6
Beech	50	70.3	34.7	12.1	42.3	6
Red oak[3]	100	91.4	46.5	16.9	63.2	7
Red oak[4]	100	82.4	44.3	13.3	65.7	7
Over-all averages		85.5	42.8	16.9	52.6	7

[1] Average of heartwood area observed on both ends of ties.
[2] Determined by ovendry method one day after kiln drying.
[3] Southern red oak and related species.
[4] Water and Laurel oaks.

Table 5.—MOISTURE CONTENT AND CREOSOTE TREATING DATA FOR 140 CROSSTIES KILN DRIED IN CHARGE 5[1]

Species	Heartwood volume per cent	Kiln-dried moisture contents[2]		Creosote retentions		Creosote penetration	
		Per cent	Standard deviation	lb/cu ft	Standard deviation	Inches	Per centage rin treated
1	2	3	4	5	6	7	
Black gum	0	42.5	9.0	7.6	1.1	1.9	
Black gum	10	49.7	8.8	7.0	0.6	1.9	
Black gum	30	58.1	11.2	6.8	0.6	1.5	
Red gum	10	69.7	16.5	6.7	0.8	2.5	
Red gum	30	77.3	24.6	6.7	0.4	1.3	
Red gum	60	70.6	18.4	6.3	1.1	1.4	
Red gum	90	58.6	21.5	6.6	1.0	1.8	
Elm	100	48.3	15.2	7.2	1.3	2.4	
Hickory	0	31.7	2.7	5.9	0.5	2.6	
Hickory	30	46.8	7.3	5.0	0.7	1.9	
Beech	20	39.2	6.7	5.3	0.3	1.8	
Beech	50	42.6	6.5	5.1	0.4	1.6	
Red oak[3]	100	60.7	7.3	4.3	0.4	1.5	
Red oak[4]	100	61.0	7.7	4.3	0.5	0.8	
Over-all averages:		54.1		6.1		1.8	

[1] Values based on average of ten ties.
[2] Determined by ovendry method on borings taken at midpoint on broad face of ties.
[3] Southern red oak and related species.
[4] Water and laurel oaks.

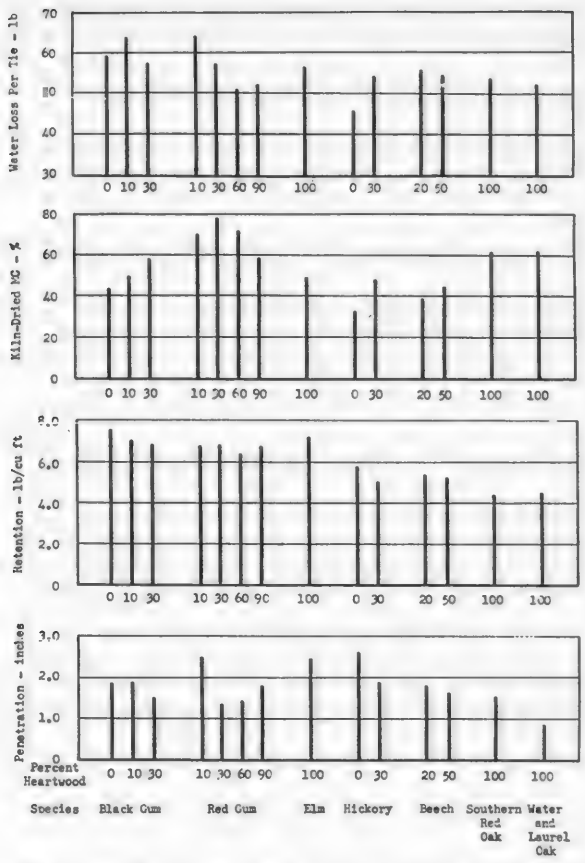

Fig. 4.—Water loss, kiln-dried moisture contents, retentions, and penetrations for 140 crossties kiln dried for 72 hours with dry-bulb temperature of 230° F. Values are based on average of ten ties.

contents in the outer 1-inch layer (8.1 to 28.9 per cent) were well below fiber saturation point, and in some cases much of the free water was removed from the second 1-inch layer (27.3 to 81.8 per cent). The core moisture contents, ranging from 40.7 to 133.9 per cent, indicate that relatively little moisture was removed from the centers of the ties. Differences in moisture contents and moisture gradients among the 14 ties can be attributed largely to differences in species and percentage of heartwood.

Preservative Treatment: In view of the fact that the most favorable moisture content for optimum treatment of wood is not definitely known (7, 9), the only test of how well the crossties were prepared for treatment was by actual measurement of how they took the preservative. The total net retentions of creosote based on tank measurements for the four treating charges were 9.23, 9.05, 7.84, and 7.71 pounds per cubic foot, respectively. These retentions were considered to be satisfactory. Creosote retentions determined by actual weight of the special test ties before and after treating (Table 5, column 5) were also satisfactory for black gum (6.8, to 7.6 pounds per cubic foot), red gum (6.3 to 6.7 pounds per cubic foot) and elm (7.2 pounds per cubic foot). The other species might have had higher retentions if the treating schedule had been adjusted for them. In spite of their low retentions, the penetration of creosote (Table 5, column 7) into the hickory (1.9 to 2.6 inches) and beech (1.6 to 1.8 inches) may be considered excellent for these ties. In regard to the southern red oak ties, the average retention and penetration (4.3 pounds per cubic foot and 1.5 inches, respectively), as well as the per cent of annual rings treated (52 per cent), cannot be considered acceptable for this species; however, if an oak-treating schedule had been employed, the results probably would have been satisfactory. The water and laurel oak group, in accordance with the previously mentioned claim, exhibited both low retentions and penetrations.

The relationships between water removed, kiln-dried moisture contents, and creosote retentions and penetrations are presented graphically in Fig. 4.

Seasoning Defects: In regard to seasoning degrade, not one of the total charge of 2016 kiln-dried crossties was rejected because of seasoning defect and none of the black or red gum ties required doweling. For the other species, the following tabulation shows the number and percentage of ties doweled:

Species	Total number of ties	Number doweled	Percentage of Total doweled
Elm	11	1	9.1
Hickory	54	5	9.3
Beech	22	7	31.8
Southern red oak and related species	11	0	0
Water and laurel oak	43	14	32.6

From this tabulation it may be seen that the water and laurel oak and beech ties were more prone to splitting under the kiln schedule employed than were the other species. Without doubt, some improvement in this regard is desirable. Overzealous inspection may have been a factor in the selection of the ties to be doweled. It may be observed in Figs. 5 and 6 that the ties were nearly free of serious defects.

For the most part, the size of the seasoning checks was much smaller than is generally observed in air-seasoned ties. Average dimensions of the most objectionable checks[4] for the 140 test ties are presented in Table 3, columns 8 and 9. The dimensions of the widest individual check observed on the top face of all ties within each of the 14 species-heartwood groups is given in columns 10 and 11. Test ties exhibiting checks wider than 0.375 and longer than 14 inches were rare.

It should be noted that the fundamental reason for drying crossties differs from that for drying lumber. For crossties, the purpose is to put the wood in a satisfactory treating condition; that is, a condition which will permit the ties to absorb and retain a specified amount of preservative and which will allow penetration of that preservative to specified depths. Seasoning checks of ¼ to ½ inch in width, though objectionable, are customarily permitted; differential stresses within the tie body apparently are not detrimental. Limited checking in the ties prior to preservative treatment may be considered desirable for some woods that are difficult to penetrate with preservatives. Other than to get satisfactory treatment there appears to be little reason to reduce the moisture content below that which it will reach in service.

The average moisture gradients were recently determined for two groups of ties in service in a main-line track in Florida during the month of March.

[4] Generally, the widest check observed on the adzed face of a tie, but sometimes a check slightly narrower and much longer is more objectionable. Location of check is also a factor; an end check or a check near the plate zone is more objectionable than one in the center of the tie.

Increment borings taken from the centers of 72 ties were extracted in toluene for six hours, and the resultant moisture contents are given in the following table.

These moisture contents appear to be low, and it is felt that further study should be made to determine more definitely the moisture gradients of ties in service.

Steam Consumption and Costs: Steam consumed during the three days of kiln drying the 2016 crossties totaled 210,807 pounds, or 104.6 pounds per tie. Steam used during the first and third days amounted to 89,325 and 57,168 pounds, respectively. Based on a steam cost of $1.50 per thousand pounds, the total steam cost for this charge was $316.21, or 15.6 cents per tie. It is realized, of course, that actual steam costs vary considerably with local conditions.

It is estimated that electric power consumed during Charge 5 amounted to 1311.05 kw-hr., or 0.6503 kw-hr. per tie. Based on the rate of 2.5 cents per kw-hr., the power cost to operate the fans during the 76-hour period amounted to $32.78, or 1.62 cents per tie. These calculations are based on the assumption that the 220 V/40 hp motor involved operated at 80 per cent of the full-load (98 amp) amperage rating.

Handling costs for the crossties were considered to be about the same as for air seasoning. Kiln-stack units (4 and 5 tiers per unit) were piled on the ground by two men per unit, and lift trucks were used to move the completed units to the kiln trucks. A five-tier unit of 40 ties required approximately 20 minutes to build. The lift truck consumed about 15 minutes to move 4 units (144 ties) from the ground on to the kiln trucks. No e-

Species and method of seasoning	Number of ties sampled	Years in service	Moisture content, per cent		
			Outer inch	Second inch	Core
Mixed hardwoods (air seasoned)	36	5–15 (Estimated)	12.1	21.5	49.2
Red and black gum (kiln dried)	36	1.2 (Actual)	11.1	18.9	32.8

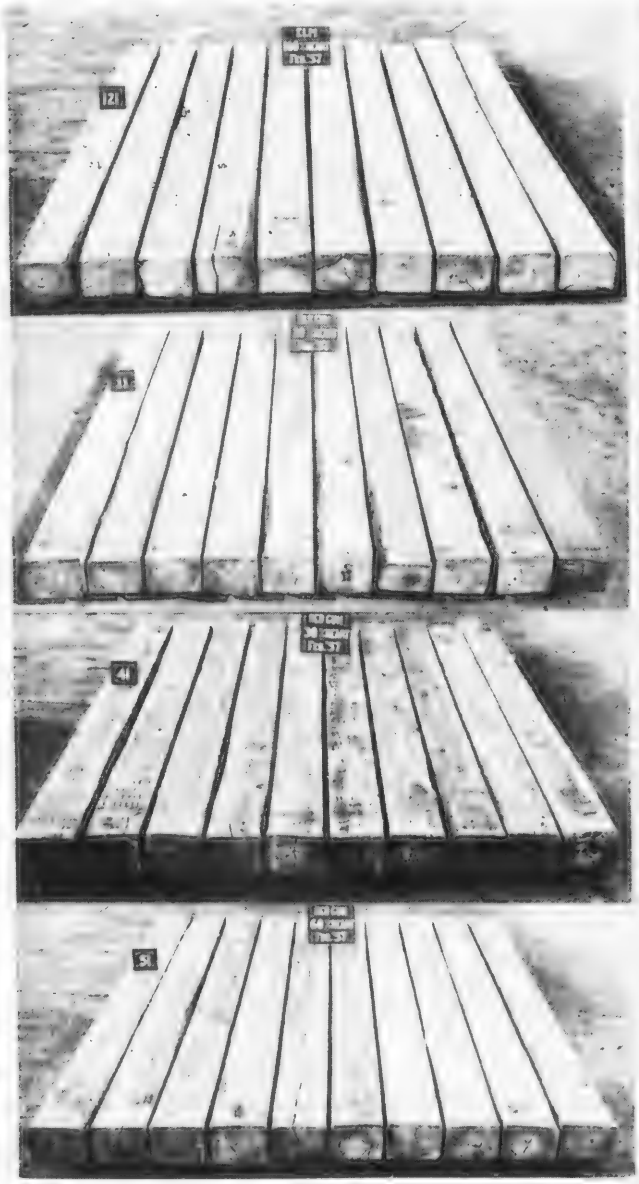

Fig. 5.—Black gum, red gum, and elm crossties after kiln drying for three days at 230° F.

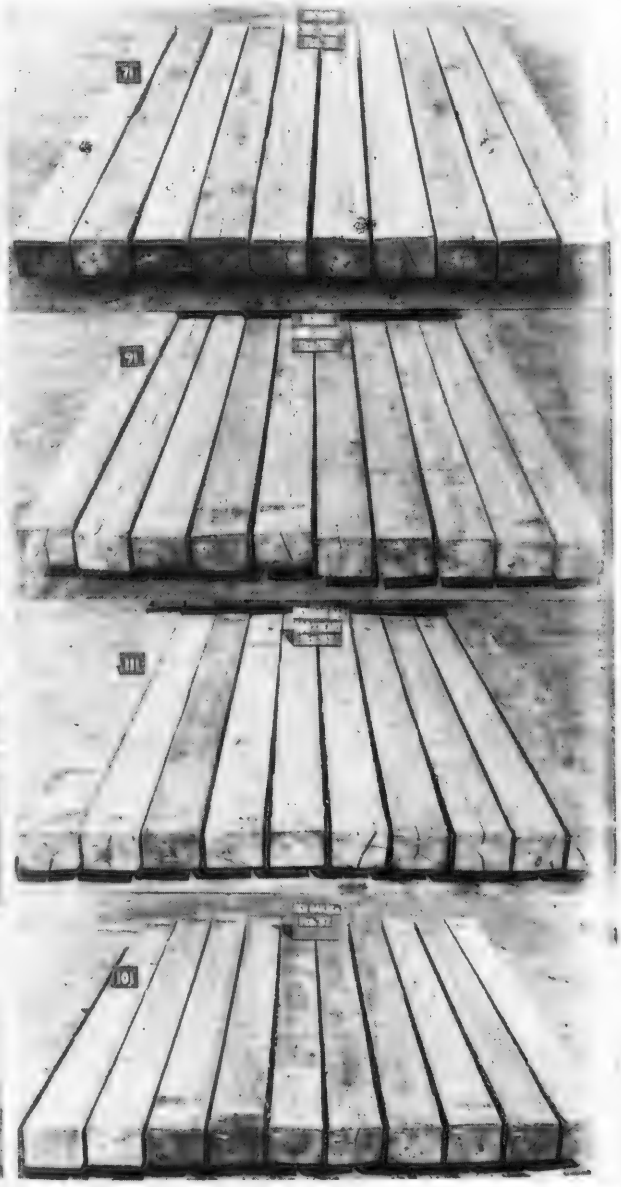

Fig. 6.—Hickory, beech, and red oak crossties kiln dried for th- days. Note the absence of serious checks and splits.

rate of the capital outlay and maintenance costs for kiln equipment and materials was prepared for the drying involved, but it is believed that the total costs for kiln drying the crossties were at a practical and economical level, and particularly so, considering the advantages gained.

Conclusions

The data collected during this study provide strong arguments for the fact that it is feasible, from both a technical and economic standpoint, to prepare green hardwood crossties for preservative treatment by kiln drying. Some of the southern hardwood species, namely black gum, red gum, elm, and hickory, responded well to accelerated drying. Further study and alterations in the drying and treating schedules may lead to more acceptable results when beech, red oak, and other species are kiln dried.

It may be concluded from the data collected that the fast, high-temperature (230° F.) kiln schedule is more satisfactory for conditioning crossties than are schedules which utilize lower temperatures over a longer period. Heat and power costs were less, water-removal rates were higher, and the size of seasoning checks was smaller when the fast, high-temperature schedule was used. Based on general observations, inspections of the crossties in track, and data collected, it may also be concluded that the surface checks, end checks, and splits in kiln-dried ties are narrower and shorter than those normally found in air-seasoned ties.

Creosote retentions and penetrations measured during this investigation indicate that kiln-dried crossties will take pressure treatment in a satisfactory manner. The effects of percentage of heartwood volume and species were demonstrated during this investigation, but in some cases, differences in initial moisture content, uncontrollable differences in heartwood volume, and other factors were probably responsible for obscuring the true effects.

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Discussion

Walker Wellford, Jr. (Wel-Dri Co.): What is the moisture content of the center of a red gum tie after three days of drying, as compared with the surface?

Mr. Huffman: In a red gum tie with a high percentage of heartwood, the moisture content at the center is practically the same as the original moisture content, while its surface is below 25 per cent. In a sapwood tie, the center moisture content may be 10 to 20 per cent below the original moisture content, while its outer one-inch is 10 to 15 per cent.

A. K. Kemp (Austin State College): What was the moisture gradient in ties that were kiln dried?

Mr. Huffman: The moisture gradient varied considerably among the different species and heartwood volumes. As shown in Table 4, the moisture contents in the outer inch ranged from 8.1 to 28.9 per cent, in the second inch from 27.3 to 8.18 per cent, and in the core from 40.7 to 133.9 per cent.

Henry A. Huber (Dow Chemical Co.): Do you have any comparisons with vapor-dried cross-ties?

Mr. Huffman: We do not have any definite comparison.

R. H. Elliott (Standard Dry Kiln Co.): What air-drying time would be necessary to obtain the same moisture content and penetration of preservative?

Mr. Huffman: On soft hardwoods we would estimate three to six months, but for oak it would take about 8 to 12 months.

George G. Marra (Washington Institute of Technology): I can understand the reduction in surface checking, but why didn't you get more end checking?

Mr. Huffman: We do not know definitely, but perhaps the high temperatures developed sufficient plasticity in the wood to yield to the developed stresses, and perhaps the fast drying caused numerous but fine, uniformly spaced checks, not too different from mechanical incising, which may have reduced the occurrence of large, objectionable checks. We did not use any end coatings.

R. C. Reitz (U. S. Forest Products Laboratory): Does your experimental work indicate any possibility that you are changing the wood properties to the extent that kiln-dried ties might require less cylinder time for preservative treatment?

Mr. Huffman: Something is happening to the wood that we do not fully understand. This phenomenon is illustrated by Charges No. 3 and No. 4, for which the cross-ties were selected from the same site at the same time and the creosote treatment was applied in the same cylinder at the same time. Only the kiln schedules differed. In charge No. 4, we removed less moisture than in Charge No. 3 in less than half the time, but obtained higher penetrations and absorptions of preservative.

John Devine (Moore Dry Kiln Co.): Is there any reason for removing anything but free water in cross-ties to be treated with a preservative?

Mr. Huffman: Yes, the removal of bound water causes shrinkage and subsequent checking, which is helpful in the penetration of the preservative, therefore some of it should be removed. On the other hand, the removal of bound water and some of the free water is not necessary to make room for sufficient quantities of the preservative.

James Hamilton (Michigan College of Mining and Technology): Would this study apply to thick lumber for other purposes?

Mr. Huffman: I do not believe it would apply to most other uses.

Mr. Hamilton: How about roof timbers, and so forth?

Mr. Huffman: I do not know exactly. The design and specifications of the structure must be considered. Further drying, shrinkage and checking might occur in some situations where it might be detrimental.

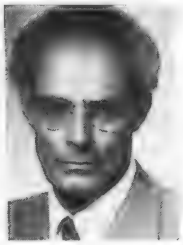
Mr. G. Marra: Several years ago, Paul Zottu dried some cross-ties by high frequency and the preservative treatment following the drying resulted in 100 per cent penetration. this would indicate that the particular type of drying may have some influence on penetration of preservatives.

William T. Nearn (Pennsylvania State University): How much time elapsed between the time the ties came out of the dry kiln and went into the cylinder?

Mr. Huffman: In the experimental kiln, it amounted to only a few days, but in the commercial kiln it amounted to several weeks.

William J. Delmhorst (Delmhorst Instrument Co.): Were the first schedules lower in temperature than the later schedules?

Mr. Huffman: Yes. The first two schedules began at 180° F. and terminated at 200° F.; the last schedules were constant at approximately 230° F. The low temperature schedules took as long as 11 days, while the high-temperature schedules took only three days.



Adhesive and Adhesion Problems in Particle Board Production[1]

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On the basis of fundamental research work, progress in particle board production should be in the direction of adhesive application and improved chip preparation. Cellular surface structure should be as undamaged as is feasible, while adhesive should be distributed as a continuous film rather than as discrete droplets.

THIS DISCUSSION OF SOME OF THE PROBLEMS of adhesion and adhesives in particle board production is based mostly on inference from recent research work on the fundamentals of adhesion in wood and, as such, is of somewhat speculative nature. This presentation was chosen, nevertheless, because it was believed that analysis of one of the most pressing problems of this industry was necessary. To assist those not familiar with the details of particle board manufacture, reference is made to an excellent survey in the field (1)[3].

Fig. I illustrates, on the basis of European experiences, the cost-factor distribution of the basic raw materials, wood and glue, and the production factors of wages, energy, upkeep, repairs, and depreciation of equipment. Similar figures for this country are not available, but the figures shown are not in contradiction with present-day current-price trends (1). They suggest immediately the need for more research to reduce the excessive cost of binder in particle board. The cost of 5 to 10 per cent binder approximately equals the cost of 95 to 90 per cent wood particles in the finished board.

Even if the cementing together of wood particles cannot be called a typical gluing operation, the variables that enter into the process are, in many respects, the same or similar to those which have been charted for the gluing process for woods (2). These, with certain modifications, can serve as a starting point for the discussion of processing variables in particle board production. From the three groups, namely 1) gluing conditions, 2) glue properties, and 3) wood properties, a few of the more important ones have been selected for closer scrutiny.

Spreading and Spread, Moisture Content, Surface Properties, Penetration, Curing

Next to the mechanical preparation of the chips or shavings, spreading the binder is the most critical and, for the quality of the bond and board, the most decisive operation. The binder is spread either as a solid, dry powder, or more commonly as a liquid. Phenolic resins are sometimes used, but urea-formaldehyde resins have received, for reasons of cheapness, versatility, and ease of application, almost universal acceptance. Spreading of the small amount of binder—usually between 5 to 10 per cent—on the tremendous surface of the chips is accomplished either through roller coating or spraying.

The process of atomization of liquid fuels, that is, the process by which an

Table 1.—SOME OF THE VARIABLES INVOLVED IN THE SPRAYING OF ADHESIVES AND AVERAGE VALUES USED

Orifice diameter (nozzle size)	O	=10–600 μ
Mean droplet diameter	d	=20–150 μ
Discharge velocity of jet	v	=100–1600 feet/sec.
Discharge rate	P	=1–4 lbs./min.
Velocity of moving chips	V	=unknown
Spray angle	$2\alpha = \theta$	=15°–85°
Cumulative volume of droplets	R	=unknown
Injection pressure of liquid	P_1	=15–50 lbs./in.
Injection pressure of air	P_a	=30–100 lbs./in.
Specific gravity of adhesives	S	=0.75–1.1
Surface tension of adhesive	η	=50–60 dynes/cm.
Absolute viscosity of adhesive	γ	=250–1300 cP.
Energy of atomization	E	=100 ergs./gr.

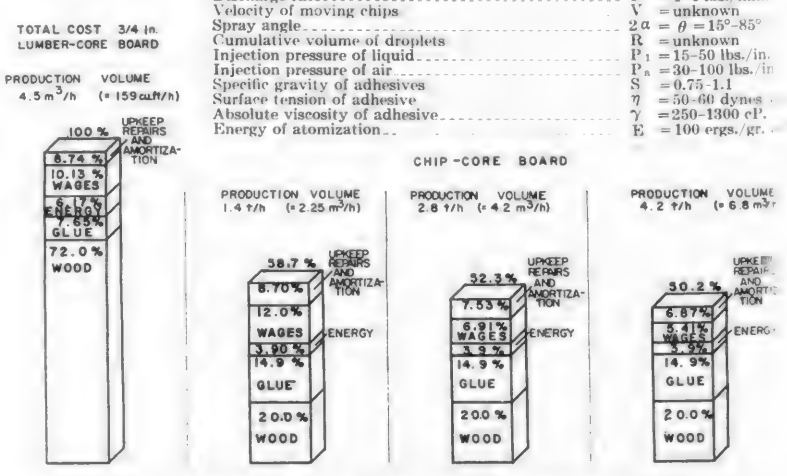


Fig. 1.—Comparison of cost-factor distribution between lumber-core and chip-core board.

[1] Presented at the Spring Meeting of the Northern California Section, FPRS, held May 2–3, 1957, in Berkeley, Calif.

[2] Some of the experimental data in this paper originated from the Swedish Forest Products Research Laboratory, Wood Technology Dept., with which the author was previously connected. The opportunity of using this material is gratefully acknowledged.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

The Author: Dr. J. E. Marian studied at the Technical University of Vienna, Austria. He was formerly in charge of adhesives and wood finishes at the Swedish Forest Products Laboratory, Stockholm.

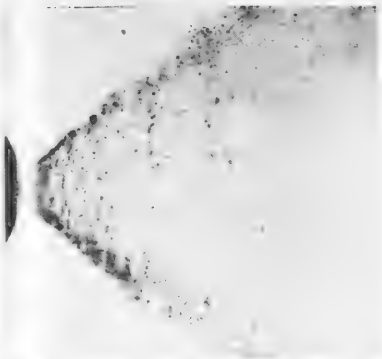


Fig. 2a.—High-speed photograph of the adhesive jet.

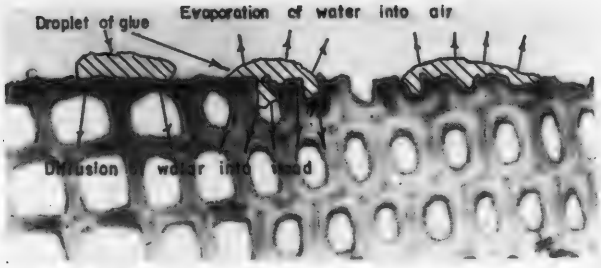


Fig. 2b.—Schematic picture of droplets on chip surface.

initially continuous liquid jet is finally broken up into a great number of small droplets, is of great importance in many combustion processes. A great amount of work has been done to determine the effect of many variables on the final result of atomization and to lead to a better understanding of the whole complex problem.

Any such work is almost entirely lacking for the atomization of adhesives. This is probably due, on the one hand, to the complicated relationships of the many physical factors involved in the atomization process, and on the other, to the practical difficulties encountered in carrying out experiments to study the behavior of high velocity sprays, composed as they are, of a very large number of droplets of various sizes, impinging on particles of wood in rapid motion.

The liquid glue enters the atomizer as an aqueous colloidal precondensate, usually with a viscosity of 250 to 1300 centipoises and a dry solids content of 30 to 70 per cent. Simple liquid pressure or air pressure injection is applied. The liquid jet leaves the orifice with an initial velocity of between 100 and 1000 feet per second at a discharge rate of 1 to 4 pounds per minute. The process of atomization of the liquid jet begins directly after the adhesive leaves the atomizer and continues during the spray movement in the surrounding air. It is not completed suddenly in an explosive manner, as has been suggested by some researchers. Instead, in sprays the subdivision of bigger droplets and particles into smaller ones goes on during the travel of the spray, until the velocity falls to a value below which all the droplets will remain stable. The extent to which this further subdivision occurs will depend on the conditions under which the spray is produced.

Recent developments in the photography of rapidly moving objects opens a possibility to measure droplet size distribution along their path, and thus compare experimental data with theoretical deductions. An example would be the validity of the Rosin-Rammler relationship (3):

$$\log \log 1/R = n \log x - k$$

where x = droplet diameter

k = constant

Some of the more obvious variables, such as spraying pressure, discharge rate, viscosity, and dry solids content, have been fairly well studied. Even the relationships between motion of the chips in the mixing chamber and spraying characteristics of the adhesives have been empirically established, especially for spraying operations of the continuous type.

Two different schools of thought advocate either a uniformly discrete droplet distribution, or the spreading of a uniformly continuous film of binder over the surfaces of the chips. Available equipment permits solely the application of the "discrete droplet" principle. In general, colloidal dispersions of high molecular precondensation products, such as urea- or phenol-formaldehyde resins, do not lend themselves very readily to fine particle spraying. One would expect rather large average particle size, which would increase with molecular weight or rather M. D. P. (mean degree of polymerization). This seems actually the case, as exploratory tests have shown. As long as the dynamic fundamentals of adhesive atomization such as cone angles and other characteristics, dispersion, droplet size distribution, energy consumption in atomization, electric phenomena, together with adhesive characteristics, such as surface tension and so forth, are not thoroughly investigated, the realization of a more even adhesive distribution will not make progress. The arithmetical and geometrical relationships between chip thickness and size, chip surface area, spread and binder consumption, mostly the work of Klauditz (4), are

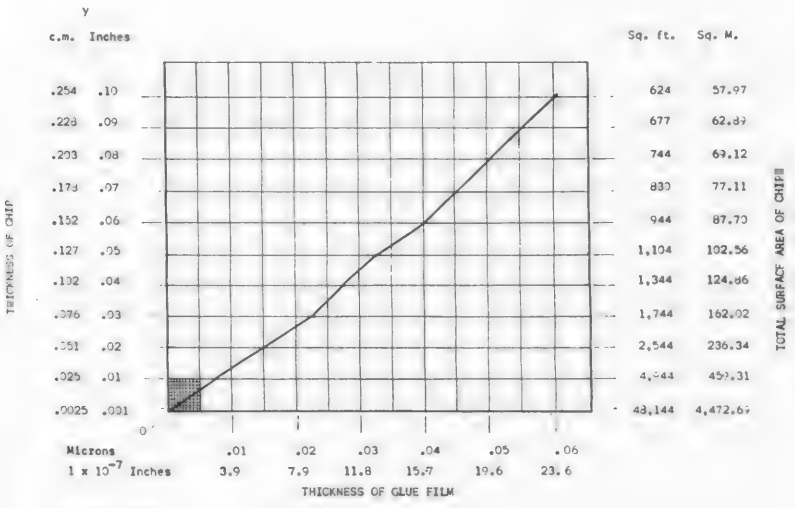


Fig. 3.—Thickness of a glue film compared to chip thickness.

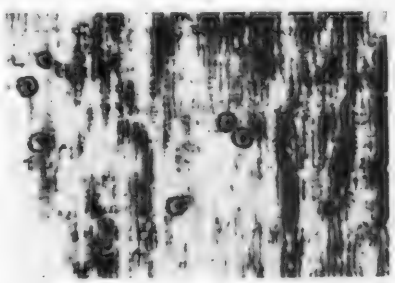


Fig. 4.—Douglas-fir chip, 8 per cent urea-resin dyed with malachite green. Notice lumps of glue in incident oblique light in circles.

fairly well established and represented by equations 1 through 4. The bonding strength is not proportional to the surface area of the chips and the binder spread, as might be concluded from equations 1 to 4, but increases with chip surface area and diminishing spread per unit of surface. This is sufficiently explained by the fact that more intimate contacts are formed between thinner chips, with thinner glue lines as a consequence. *This is the strongest argument in favor of the continuous glue film hypothesis.*

$$A = \frac{0.2}{r \times d} \qquad (1)$$

$$S = \frac{r \times d}{0.2} C \qquad (2)$$

$$A.S = C \qquad (3a)$$

$$A.S = \text{const.} \qquad (3b)$$

$$D = \frac{L}{r \times d} \qquad (4)$$

where A = Area of surface of chips =
= m² 100 g. absol. dry wood or 1000 sq. ft./-lbs. dry wood
S = Spread quantity of dry binder =
= g./m² quantity of dry binder or
= lbs./1000 sq. ft. quantity of dry binder
C = Consumption of binder =
= g./100 g. abs. dry wood
= lbs./lbs. abs. dry wood
r = Density of wood
= g./cm.³ or
= lbs./cu. ft.
d = Thickness of chips =
= m/m or inches.
D = Degree of slenderness =
= Ratio of length L: Thickness d.

Practical experience and experimental results show that the bonding strength—chip thickness curve goes through a maximum. In other words, bonding strength is less for very thick or very thin chips. This has been surmised already by Turner (5). He stated that extremely thin flakes do not render highest strength boards because of damage to cellular structure near the surface through machining. Recent researches give an explanation for these findings and views. (6, 7).

Various preparatory machining steps as shown in Fig. 5 give varying degrees of surface damage or intactness of cellular structure. It is quite an acceptable explanation that, in chips of diminishing thickness, the fraction of damaged surface increases, figured on the total chip thickness.

Fig. 6 illustrates the point that perfect joints can be obtained with very sparing spreads, that is, about 2 lbs./1000 sq. ft. *if only undamaged surfaces are produced and bonded.*

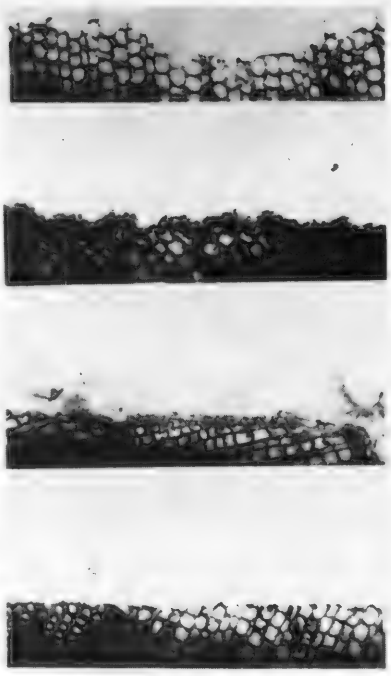


Fig. 5a.—Microscopic cross sections after various types of surface preparation methods: a), rotary-cut veneer, b), circular saw, c), hand sanded, d), hand planed.

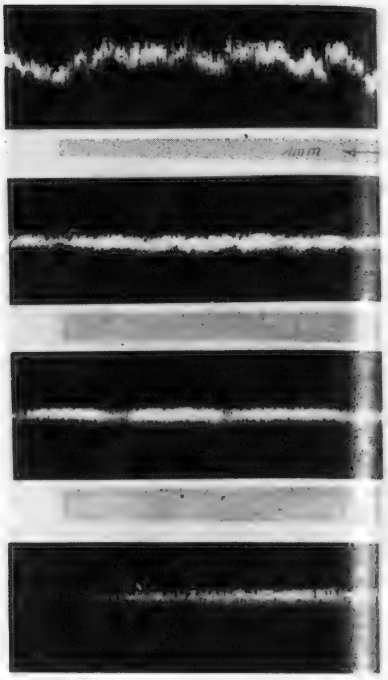


Fig. 5b.—Light-section profiles after various types of surface preparation methods: a), rotary-cut veneer, b), circular saw, c), hand sanded, d), hand planed.

No method for measuring adhesive distribution is known. Measurements of electrolytic conductivity of extracts of chips are evidently unsatisfactory (8). Combination of optical and statistical methods will be attempted at the Forest Products Laboratory of the University of California, based in part on earlier work (9). The determination of adhesive distribution on the surfaces of chips is one of the most pressing problems of particle board production. Unless this problem is satisfactorily solved, progress in binder application and economy is difficult to visualize.

Moisture Relationships

The moisture content of the wood particles and the moisture added with the adhesive affects both the plasticity of the wood during the pressing cycle as well as the flow of the resin. These relationships are fairly well investigated and understood.

Certain aspects seem to have been neglected, however. How uniform is

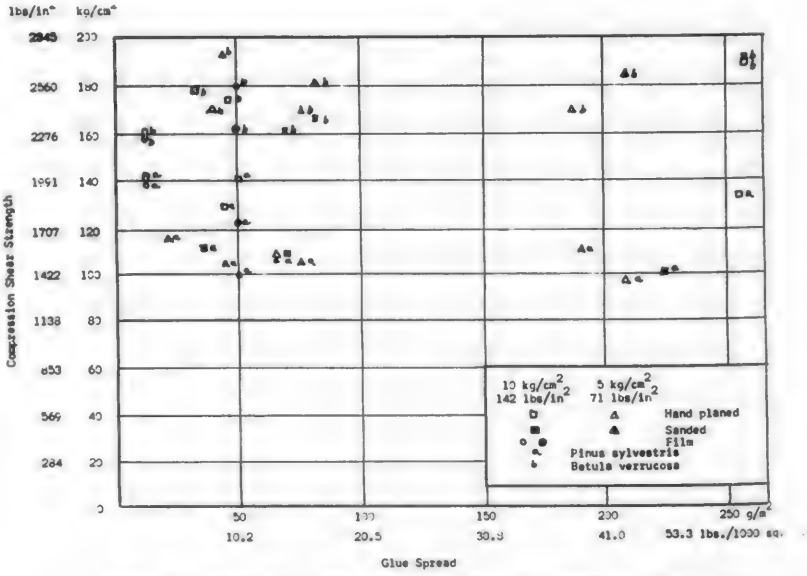


Fig. 6.—Comparison of shear strength as a function of spread.

moisture distribution in the chips? Droplets impinging on the surface will lose a certain amount of water during the spraying operation, and still more when violently agitated in an air-stream in the mixing chamber. If water is dissipated through diffusion and evaporation, can the bonding of the particles be considered to be essentially a "dry film" operation? The transfer of binder from chip to chip, as claimed by many inventors and owners, has not been confirmed by experiments or practical experience. In view of the cellular, fibrous surface structure, the existence and activity of strong capillary forces may be assumed. Loss of moisture of the droplet on the chip surface through diffusion or evaporation will increase viscosity of the binder. Transfer through any wiping action between particles is therefore *highly improbable,* and conditions during the pressing cycle must closely approach those prevailing under strictly "film gluing" operations.

Through inference from the author's previous and current investigations. it may be concluded that the maximum of bond strength will be at 8 to 12 per cent moisture content *at the interface.*

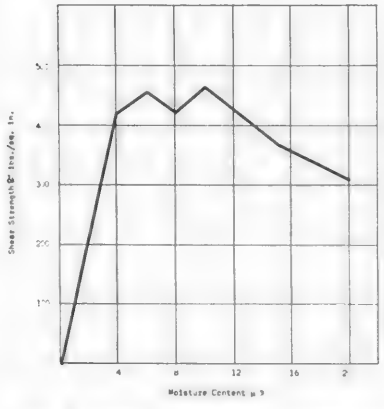


Fig. 7.—Shear strength as a function of moisture content of the veneers before they are glued into plywood.

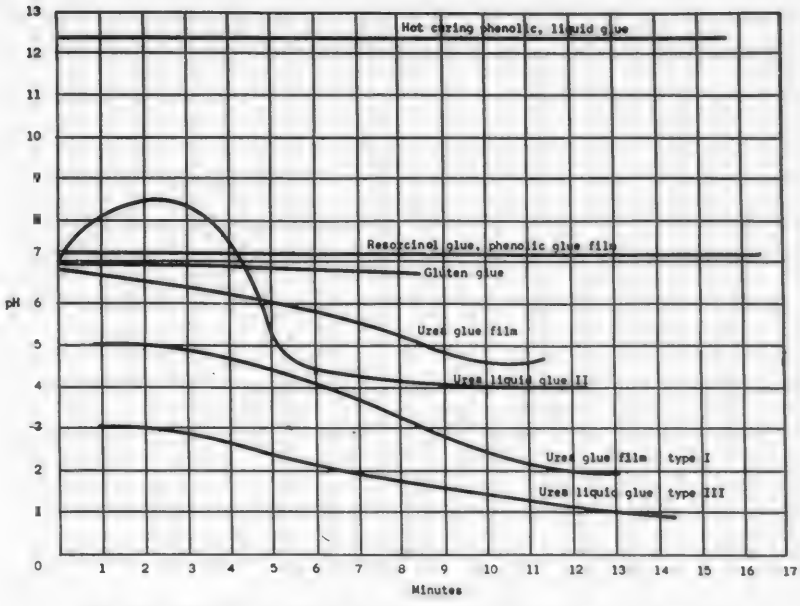


Fig. 10.—Changes of pH as a function of time during pressing cycle.

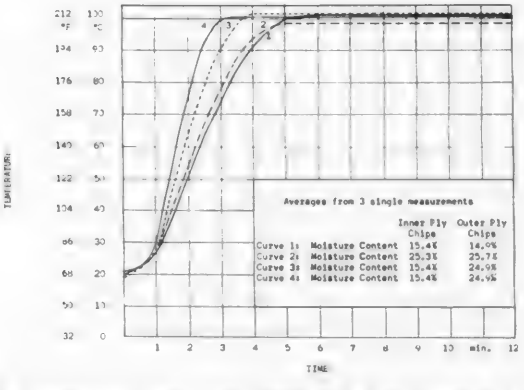
This is in good agreement with over-all experience. However, a migration of moisture must be expected during contact of the chips with the hot-press platens. This is demonstrated by recent work of Kollmann (10).

The accelerated rise in temperature in the middle of the panels is evidently due to the migration of steam from the panel surface and to the enhanced heat transfer resulting from it (11).

A brief consideration of the relationship of moisture content, penetration, and rate of setting is probably appropriate at this point.

The accurate role of water in the setting of resin adhesives, urea and phenolics, is not fully understood. Moisture, which has to be heated, retards the cure, increases penetration especially with phenolics, and causes crazing of the glue lines in ureas if present in excessive amounts. Moisture, as superheated steam circulating around the chips inside the panels, accelerates the rate of setting. The rate of setting again depends, provided other factors are identical, on the character of the pH-time curve during the minutes of the pressing cycle (12).

Penetration will be the result of these variable factors. It should be noted in this connection that penetration into *undamaged* wood surfaces can only mean a flow into the cavities of the tracheids, either filling the troughs of vessels or through their cut-off ends. Penetration of the high-molecular resin substance *through the cell walls* has never been observed and actually never takes place. Penetration through the cracks, fissures, and ruptures of the damaged wood in veneer, for instance, is, of course, everyday experience. High moisture content will be the cause of increased flow, whether through slower rate of setting or simply through a carrying off of the dissolved resin fractions, especially those of lower degree of polycondensation. Rapid increase in temperature will accelerate rate of setting (approxi-


Averages from 3 single measurements
Inner Ply Chips
Outer Ply Chips
Curve 1: Moisture Content 15.4% 14.9%
Curve 2: Moisture Content 25.3% 25.7%
Curve 3: Moisture Content 15.4% 24.5%
Curve 4: Moisture Content 15.4% 24.9%
TEMPERATURE
TIME

F 8.—Temperature—time curves, measured in the middle of 3-ply nels; varying moisture contents in inner and outer ply chips.

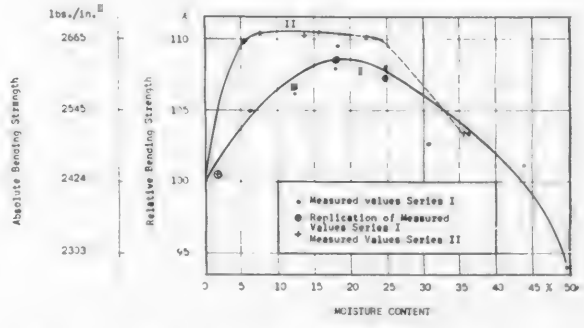


Fig. 9.—Changes in absolute and relative bonding strength in 3-ply chip board with increasing moisture content in the outer plies under identical pressing conditions.

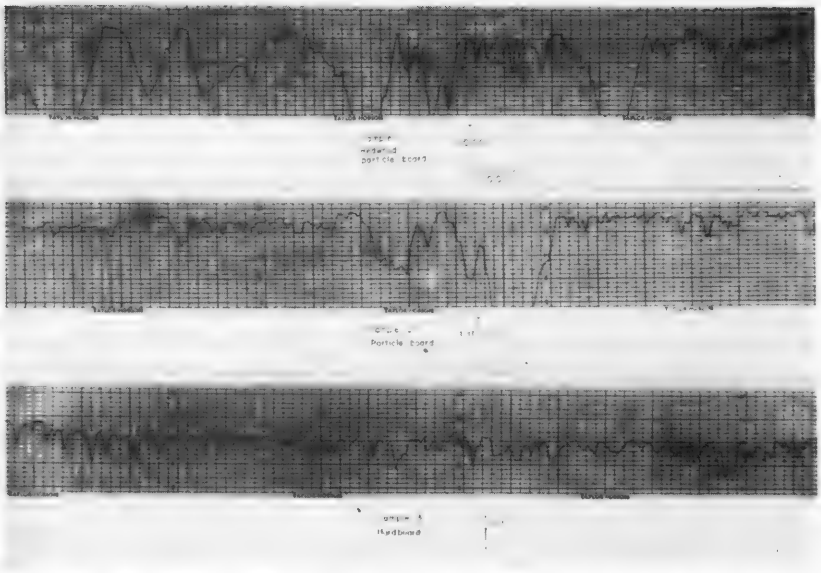


Fig. 11.—Surface profile curves in various wood panels as measured with a Talysurf instrument.

mately doubling the rate for each 10° C. or 50° F.), and decrease viscosity initially and increase it at the setting, when the resin is finally transformed into the insoluble and unmeltable state. Heating the wet mass of chips will plasticize not only the wood but also melt the adhesive, thereby decreasing its surface tension and enhancing the wetting of neighboring surfaces and the transfer of adhesive to these. A delicate balance and simultaneous change of these factors decide the actual position of the equilibrium at the end of the pressing cycle.

Increased moisture content in the chips of the outer ply imparts greater mobility to the wood, whereby an improvement of surface smoothness can be obtained (13).

Conclusions

From consideration of these facts, it may be concluded that progress in adhesive application in particle board, combined with improved chip preparation, ought to be sought, perhaps along the following lines:

1. Production of chips with as undamaged, as perfactly intact cellular surface structure as is technically and economically feasible. This can probably be realized through imitation of the hand-planer-knife mode of action; in effect, a slicing cut of wet wood rather than cleavage, tearing, or crushing action of dry material through the tools employed.

2. Distribution of the adhesive rather as a continuous film than as discrete droplets or lumps on the chip surface.

3. Prevention of any undesirable penetration by properly chosen pressing-cycle conditions, types of catalysts, and if necessary, by development of new adhesive processes.

In the foregoing study, an attempt was made to suggest certain avenues of approach to the more economical and technically improved application of adhesives for the production of particle board. It is hoped that research along these paths may actively contribute to the solution of some of the problems of this new industry.

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Relationship of Specific Gravity to Moduli of Rupture and Elasticity in Commercial Hardboard[1]

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Thirty-six types of commercial hardboard were tested in static bending. Test results were analyzed statistically and predicting equations were derived. Significant correlations existed for almost every type of hardboard tested, although no one equation could give reliable results for all types of hardboard when correcting for modulus of rupture or elasticity for specific gravity differences.

PRODUCERS AND USERS OF HARDBOARD have been handicapped by a scarcity of reliable information about relationships of mechanical properties to physical characteristics of hardboard. Considerable information on relationships between manufacturing variables and board strength undoubtedly has been developed within plant laboratories; few data, however, have been published.

Currently accepted practice is to use modulus of rupture as an index of hardboard properties, although some other physical property might be satisfactory for this purpose. One perplexing problem that faces the hardboard producer or researcher is the difficulty in compensating for differences in specific gravity when comparing strength properties of hardboards with differing values for modulus of rupture.

While Wilcox (3, 4, 5)[1], and Stillinger and Coggan (1) reported findings of the effect of various process variables and moisture relationships on flexural properties of laboratory and commercial hardboard, little or no information was obtained relating to the relationship of specific gravity to flexural properties of hardboard.

The U. S. Forest Products Laboratory, at Madison, Wis., undertook a comprehensive study of variables encountered in the manufacture of fiberboard.[2] Part of the study dealt with the relationship between specific gravity and modulus of rupture. The following conclusion was reached. "For practical purposes, the modulus of rupture may be assumed to be directly related to the square of the specific gravity" (2). The result was based on laboratory-size specimens manufactured from wood-fiber pulp with no additives. The range in specific gravity was from 0.15 to 1.2.

In the course of testing hardboard at the Oregon Forest Products Research Center, the practice of adjusting specific gravity to a common base came into question. The relationship of modulus of rupture to specific gravity in commercial hardboards did not appear to be the same for all kinds of boards; furthermore, relationships varied considerably among boards of one class or thickness, and among similar boards from one producer. Preliminary work suggested reliable corrections for specific gravity could be made only when appropriate factors were available for each board type from which test specimens were selected. Lack of such factors, and lack of previous work over the broad scope of current commercial hardboard, prompted the present investigation.

Definitions: Throughout this report, certain descriptive words have been used that may cause some confusion. For the purposes of the report, they are:

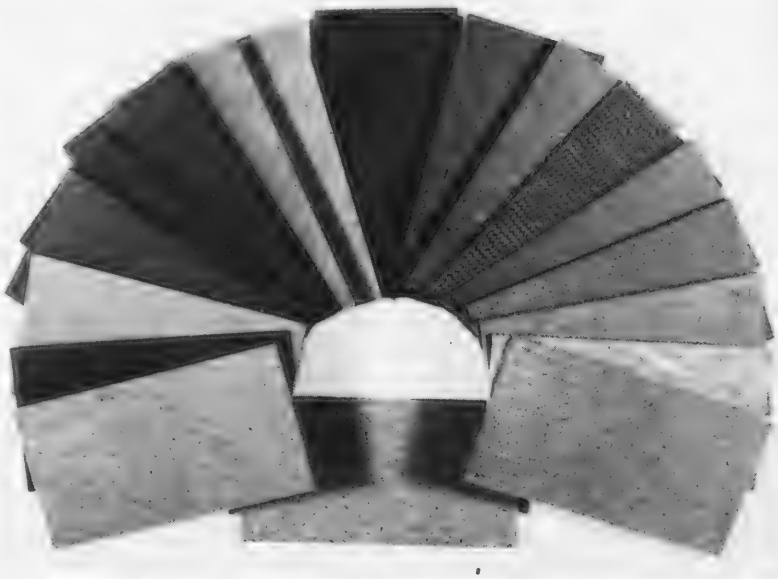
Class: There were two classes of hardboard; untreated and treated.

Board type: Hardboard of one class, one thickness, and from one producer.

Board or sheet: A 4- by 4-foot or 4- by 8-foot piece of hardboard.

Test specimen: A comparatively small piece of hardboard cut from a board or sheet.

Machine direction: Orientation of the board with respect to its line of flow in the pressing operation during manufacture.



Some of the 36 hardboard types studied at the Oregon Forest Research Center to determine the relationship between strength properties and specific gravity.

[1] Submitted for publication April, 1957.

[1] Numbers refer to the Literature Cited at the end of this paper.

[2] Fiberboard is a term applicable to a sheet material manufactured of refined or partly refined vegetable fiber. These board products are manufactured in densities from 2 to about 90 pounds per cubic foot. Hardboard has a density range of 50 to 70 pounds per cubic foot. Density values must be considered as approximate, since properties vary with base materials, binders, impregnants, and methods of manufacture.

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Objective: The objective of the investigation was to determine relationships between specific gravity and flexural properties of commercial hardboard; specifically, modulus of rupture, modulus of elasticity, maximum work, and work to 0.2-inch deflection. It was assumed the ultimate goal would be to devise an acceptable method to correct for differences in specific gravity among various types of commercial hardboard when comparing strength properties. For this reason, the study included a range of three thicknesses, two classes, and 11 producers of commercial hardboard in the United States and Canada.

Scope: Thirty-six different types of commercial hardboard were included in the study. Eleven producers (or sources of raw material), five basically different processes, three thicknesses, and two classes (treated and untreated) were represented in the study.

Results of static bending tests were analyzed statistically to determine relationships of specific gravity to modulus of rupture, modulus of elasticity, maximum work, and work to 0.2-inch deflection. Results of the statistical analysis for maximum work and work to 0.2-inch deflection were inconclusive and therefore have not been included in this report.

Table 1.—RELATIONSHIPS OF SPECIFIC GRAVITY TO MODULI OF RUPTURE AND ELASTICITY IN COMMERCIAL HARDBOARDS

Board	Specific gravity range		Predicting equation[1]	
	Low	High	Mod. of rupture	Mod. of elasticity
Untreated, ⅛-inch				
1	0.919	1.040	10,502 x — 5,475	1,260 x — 632
2	0.930	1.069	6,247 x — 862	727 x — 183
3	0.817	1.044	11,889 x — 5,801	806 x — 232
4	0.838	1.022	9,106 x — 3,357	921 x — 272
5	0.872	1.058	9,335 x — 3,259	491 x — 208
6	1.000	1.111	14,056 x — 7,638	1,634 x — 705
7	1.074	1.242	14,833 x — 12,315	1,343 x — 836
8	1.007	1.165	9,213 x — 5,563	680 x — 118
9	0.991	1.136	7,264 x — 3,298	307 x + 112
10	0.870	1.045	12,104 x — 6,126	1,069 x — 471
Untreated, 3/16-inch				
11	1.003	1.069	22,451 x — 16,376	1,634 x — 705
Untreated, ¼-inch				
12	0.904	1.044	15,726 x — 9,778	998 x — 372
13	0.955	1.080	9,249 x — 4,266	1,031 x — 542
14	0.865	1.064	13,211 x — 6,705	803 x — 181
15	0.840	1.031	12,902 x — 6,024	786 x — 212
16	0.891	1.090	16,995 x — 10,095	1,013 x — 379
17	0.748	1.069	13,190 x — 6,146	1,281 x — 483
18	0.742	1.002	11,576 x — 5,279	1,373 x — 549
19	0.823	1.072	14,378 x — 8,426	2,044 x — 1,262
20	0.981	1.188	14,651 x — 10,148	1,406 x — 925
21	1.083	1.159	8,379 x — 3,990	232 x + 286
22	0.847	1.006	10,355 x — 5,566	1,036 x — 458
Treated, ⅛-inch				
23	0.983	1.112	20,328 x — 12,159	1,476 x — 645
24	0.816	1.077	15,586 x — 7,431	1,293 x — 509
25	0.913	1.074	16,050 x — 7,317	404 x + 361
26	0.997	1.069	16,679 x — 9,053	1,594 x — 517
27	0.953	1.139	12,240 x — 4,491	1,006 x — 263
Treated, 3/16-inch				
28	1.060	1.122	3,037 x + 5,072	571 x + 508
Treated, ¼-inch				
29	1.029	1.118	21,574 x — 14,115	1,047 x — 221
30	0.893	1.049	13,701 x — 6,065	959 x — 302
31	0.889	1.083	10,931 x — 2,189	913 x — 162
32	0.921	1.038	13,571 x — 5,780	1,005 x — 257
Utility, ¼-inch				
33	0.742	0.969	9,223 x — 3,774	683 x — 188
34	0.782	0.855	15,518 x — 8,423	1,354 x — 522
35	0.757	0.925	12,182 x — 5,785	969 x — 337
36	0.796	0.916	11,080 x — 5,667	801 x — 247

[1]Where x is specific gravity, and modulus of rupture or elasticity is equal to the entire expression for each hardboard.

Procedure

Each of the 36 types of hardboard was represented by five 4- by 4-foot sheets selected at random by the producers' personnel. The sheets were cut into 12-inch squares and numbered in a uniform pattern from 1 to 16. By means of a table of random numbers, 12 of the 16 squares were selected for experimental purposes. The 3- by 12-inch test specimens were cut with their longitudinal axes parallel to the machine direction from six of the squares, and perpendicular to the machine direction in the other six squares. Thus, for a given board type, there were 12 specimens for each of the five 4- by 4-foot sheets, or a total of 60. Since there were 36 types of hardboard, the total number of specimens was 2,160.

The test specimens were stored in a heated building with no temperature or humidity control for three months prior to testing to simulate conditions practical for manufacturers who want to test their own products. Examination of coupons cut from the test specimens at time of test indicated virtually all specimens had reached a state of moisture equilibrium. All test specimens were measured to the nearest 0.01 inch in width with a modified gage comparator of the type described in ASTM Standard D 1037–52T, and to the nearest 0.001 inch in thickness with an Ames dial mounted over a plane table.

Loads were applied and measured with a Baldwin Tate-Emery air-cell weighing system attached to the movable crosshead of an electro-mechanical testing machine. Loads were applied in the centers of specimens over a span of 8.1 inches and were read to the nearest 0.5 pound. A head speed of 0.5 inch per minute was used, and load-deflection curves were drawn for each test specimen.

After each test specimen was broken in bending, a 1- by 3-inch coupon was cut near the area of failure and weighed immediately. After the coupons were weighed, they were placed in an oven and dried to constant weight at 212° ± 3° F. Initial and final weights of the coupons and their volumes, determined by the mercury-immersion method, furnished data for calculation of moisture content at time of test and specific gravity based on oven-dry weight and oven-dry volume.

The relationships between specific gravity and modulus of rupture, modulus of elasticity, work to 0.2-inch deflection, and work to maximum load were determined statistically by regression and correlation studies.

Many comparisons could be made from the collected data. The method adopted in the present study for comparison purposes was to determine the respective correlation and regression coefficients of specific gravity on modulus of rupture or modulus of elasticity, and then statistically compare these regressions and correlations for significant differences. If no significant differences existed, then a common regression or correlation value could be used; conversely, significant differences meant that the flexural properties of a board type needed to be determined by their respective regression or correlation coefficients when accurate predictions were desired. The resulting physical properties then were compared visually or statistically.

Persons interested in a more complete explanation of statistical methods followed than space allows here may obtain a supplement to this report from the Forest Products Research Center on request.

Results and Discussion

Relationships of specific gravity to maximum work, or to work to 0.2-inch deflection, were such that reliable equations could not be developed for many hardboards tested. The statistical analysis showed relationsh

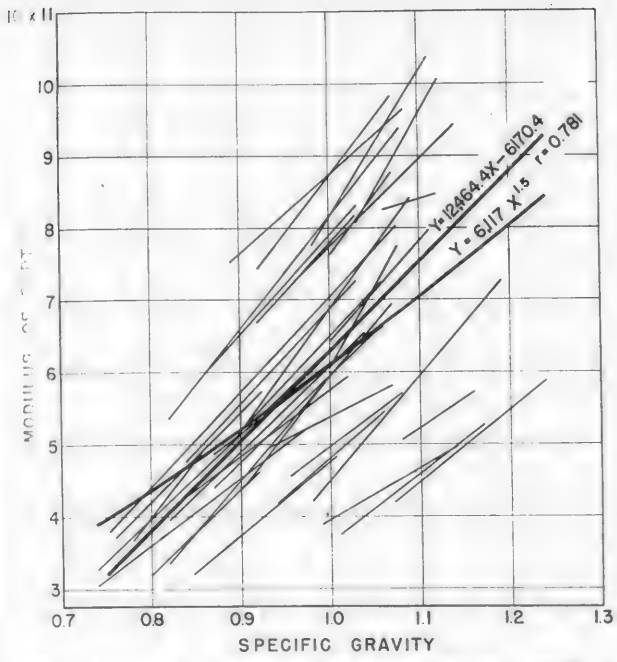

Fig. 1.—Relationship of specific gravity and modulus of rupture for 36 hardboard types as determined by analyses of regression.

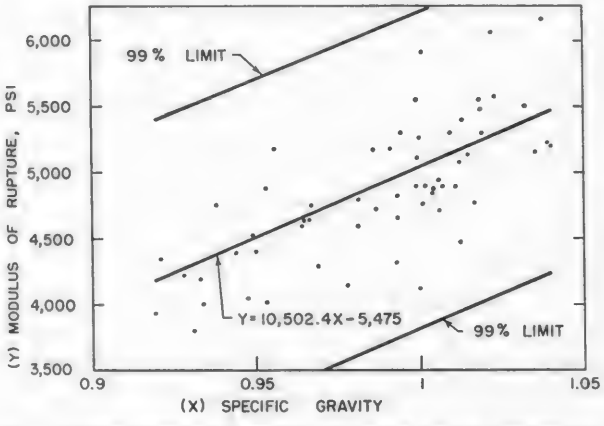

Fig. 3—Scatter diagram of modulus of rupture for 60 specimens of hardboard type 1, with formula and confidence limits.

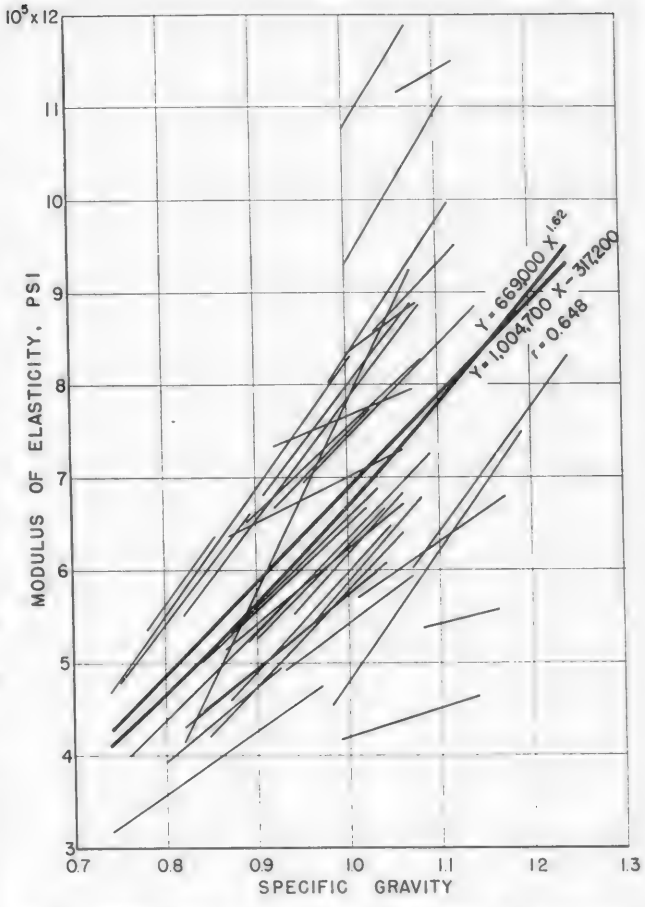

Fig. 2.—Relationship of specific gravity and modulus of elasticity for 36 hardboard types as determined by analyses of regression.

of specific gravity to moduli of rupture and elasticity, however, and allowed the derivation of fairly reliable equations.

Derived equations, and ranges in specific gravity of hardboard for which the equations were calculated, are listed in Table 1. Curves for each equation for moduli of rupture and elasticity are shown in Figs. 1 and 2 for each of the 36 hardboards tested. General equations for all 36 types were calculated by two variations of statistical methods. Of the general equations, the two that produced straight lines when plotted in Figs. 1 and 2 appeared to fit the data more closely than did the two plotted curves.

The desirability of developing individual equations for different board types is apparent from inspection of the wide spread in equations shown in Table 1. A quick indication of relationships for a particular board can be had by plotting points for specimens of several specific gravities and fitting a curve to the points.

When such information is lacking for a given hardboard, a general formula such as shown in Figs. 1 and 2 will provide a means of partially correcting for differences in specific gravity.

The curve plotted in Fig. 3 from the formula developed for one board studied (board 1 in Table 1) can provide an example of a method to follow for other boards. Note in Fig. 3 that, at 0.95 specific gravity, the formula curve shows an average modulus of rupture of 4,500 pounds per square inch. A specimen of similar hardboard, but with specific gravity of 1.02 could then be expected to have a modulus of rupture somewhere in the neighborhood of 5,250 pounds per square inch. The scatter of observations indicates any single specimen, however, may vary considerably from the average.

The interpretation of results was based solely on data obtained over the measured range in specific gravity for each board type included in the study, and should not be construed to hold for the entire specific gravity range of 0.75—1.25 for hardboard. This limitation does not invalidate comparisons here, but indicates that judgment must be used in evaluating differences in specific gravity and properties of hardboards other than those included in the study.

Because of roughly parallel alignment of fibers during board formation, some board types exhibit directional properties. These directional properties sometimes have a significant effect on modulus of rupture and modulus of elasticity, and whenever this effect occurs, accuracy of predictions can be increased by deriving an equation for each machine direction. Significant directional properties were disregarded in this study, however.

Conclusions

It is recognized that hardboards not included in the study may or may not have similar specific gravity—strength relationships, but the following conclusions are drawn from results of the investigation applied to most hardboard made in the United States in 1953:

1) Significant correlations were found to exist between specific gravity and modulus of rupture and between specific gravity and modulus of elasticity in nearly all board types studied.
2) No one single equation gave accurate corrections for moduli of rupture or elasticity when compensating for differences in specific gravity for all types of commercial hardboards studied.

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Wood Failure—Within Species and Between Species

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Estimates of bond quality are often based solely on percentage of wood failure. A discussion of the relationship between wood failure, species, and glue strength indicates that wood failure must be qualified by the species glued to describe bond quality.

DURING THE PAST 30 YEARS, estimates of bond quality based upon wood failure have been gradually accepted and used for a number of purposes. In terms of number of tests, or volume of production, possibly the greatest use is for quality control purposes in the plywood industry. Other uses include research and glue acceptance, for both laminated and crossbanded constructions, and it has been suggested that estimates of bond quality based upon wood failure are superior for all purposes to those based upon mechanical tests.

In spite of local or even quite widespread acceptance, there are certain problems that tend to limit the use of wood failure as a universal estimate of bond quality. One of these, which was mentioned in a previous paper[2], is the interesting anomaly that in certain cases wood failure increases as the failing load increases, while in other cases the opposite is true and wood failure decreases as the failing load increases.

An example where wood failure may vary directly with failing load is that of the plywood shear test, which is standard for Douglas-fir plywood quality control. That is, the case of a single species and a standardized method of breaking the wood. The chapter "gluing characteristics of different woods" in Truax's "The Gluing of Wood"[3] contains an illustration that wood failure can vary inversely as the failing load. Bergin[4] presents comparable data that also illustrate this point. Another example occurs in a discussion of the influence of species in knife testing in which Knight[5] states "It is admittedly less common to find high numbers (per cent wood failures) in the bonding of some heavy woods than it is with those of lighter weight and softer texture". The last three examples refer to the wood failures obtained with different species, when they are bonded with a single adhesive, and when the species include woods with strengths that vary from "weaker than the glue" to "stronger than the glue".

Fig. 1 has been prepared in an attempt to explain the reasons for these opposite trends. On the horizontal or *x* axis is plotted bond strength, from zero to stronger than the strongest wood. These strengths would all have to be determined by a single method of test with specimens of standard design, but the method employed would be immaterial. On the vertical or *y* axis is plotted per cent wood failure from zero to 100 per cent. The sloping line *AB* represents the linear correlation between per cent wood failure and bond strength for a weak wood (such as western red cedar) while the line *DE* represents the similar correlation for a strong wood (such as hickory).

The line *CEG* represents the linear

[1] A contributed paper (August, 1957) from the FPL's of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources.

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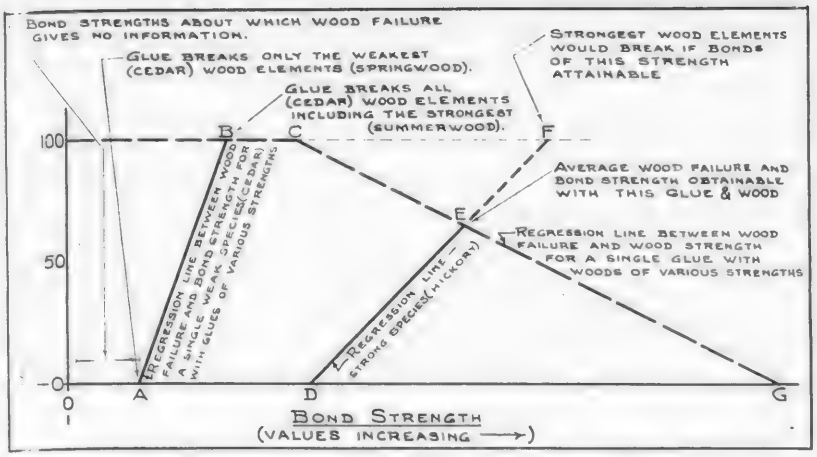
BOND STRENGTHS ABOUT WHICH WOOD FAILURE GIVES NO INFORMATION.
GLUE BREAKS ONLY THE WEAKEST (CEDAR) WOOD ELEMENTS (SPRINGWOOD).
GLUE BREAKS ALL (CEDAR) WOOD ELEMENTS INCLUDING THE STRONGEST (SUMMERWOOD).
STRONGEST WOOD ELEMENTS WOULD BREAK IF BONDS OF THIS STRENGTH ATTAINABLE
AVERAGE WOOD FAILURE AND BOND STRENGTH OBTAINABLE WITH THIS GLUE & WOOD
REGRESSION LINE BETWEEN WOOD FAILURE AND WOOD STRENGTH FOR A SINGLE GLUE WITH WOODS OF VARIOUS STRENGTHS
REGRESSION LINE BETWEEN WOOD FAILURE AND BOND STRENGTH FOR A SINGLE WEAK SPECIES (CEDAR) WITH GLUES OF VARIOUS STRENGTHS
REGRESSION LINE — STRONG SPECIES (HICKORY)
100
50
0
A
B
C
D
E
F
G
BOND STRENGTH
(VALUES INCREASING →)

Fig. 1.—The interrelationship of wood failure, wood strength, and glue strength in the testing of wood bonds.

correlation between per cent wood failure and strength of bond for a single glue and a wide range of wood species, all of which have wood elements that are "stronger than the glue". The horizontal extension of this line, from *C* to the *y* axis, is the upper limit of wood failure (100 per cent) for species that are "weaker than the glue". These lines are adapted from the data presented by Truax[3] in Fig. 14, page 45.

It is possible to start with a very weak glue, or with a process that would produce a very weak bond with a glue of high potential strength. Suppose that joints are prepared with this weak glue (or process) in both cedar and hickory. Since the wood is stronger than the glue, estimates are available of the bond strength of the glue from both the cedar and hickory specimens. Both species would presumably develop somewhat the same failing loads. Now suppose that the strength of the glue is increased until it is just good enough to take some of the (cedar) wood with it upon being broken, that is, increased to point *A* of Fig. 1. By continuing the process of increasing the strength of the glue and testing both cedar and hickory specimens, point *B* is reached. Once again, the breaking loads developed from both species would be expected to be similar but now, whereas the hickory would still show no wood failure (zero bond quality as measured by per cent wood failure), the cedar would show 100 per cent wood failure (100 per cent bond quality as measured by per cent wood failure). The glue could now be said to be as strong as the cedar. From this point on, wood failure would remain at 100 per cent for cedar specimens as glue strengths were increased.

For hickory specimens, wood failure would remain zero until point *D* is reached. At this glue strength, the adhesive would just commence to pull hickory fiber (zero bond quality as measured by per cent wood failure). A further increase in the glue strength to the maximum for that particular glue would lead to point *E*. The interpretation of the wood-failure—strength relationship at this point *E* is as follows: this particular glue is capable of breaking only 65 per cent of the wood elements in this species (the 65 per cent is fictitious, the figure given by Truax for hickory being approximately 55 per cent). In other words, 65 per cent of the wood is "weaker than the glue", while the remaining 35 per cent is "stronger than the glue". These figures, of course, are averages, and some of the wood failures entering into these averages would be as high as 100 per cent, providing the high wood failures to which Knight has referred in the quotation "It is admittedly less common to find high numbers in the bonding of some heavy woods". If it were possible to change to a sufficiently strong glue, one might eventually arrive at a point *F*, 100 per cent wood failure for hickory.

The above provides a plausible explanation of the inter-relationship between wood failure, species, and glue strength. In practice, there is a large number of species for which regression lines such as *AB* or *DEF* might be prepared. For each specific glue there would be some point *C* at which all species weaker than the glue will yield 100 per cent wood failure, whereas all species that are stronger than the glue will yield less than 100 per cent average wood failure for joints prepared with this glue under ideal conditions. The regression line *CEG* indicates this relationship for this glue. Another glue, of different strength, would provide a similar line with a different point *C*.

Barring such strength defects as loose fiber, lathe checks, or seasoning checks, the position of point *A* is determined by the strength of the weakest wood element (springwood) of that piece of wood. The position of point *B* is determined by the strength of the strongest wood element (summerwood) for that piece. For the stronger species, point *D* corresponds to point *A* and point *F* to point *B*. Glues with strengths between zero and *A* have no bond quality, as measured by per cent wood failure, when assessed by means of cedar specimens. At strengths in excess of *A* they have bond qualities ranging from 1 to 100 per cent. When assessed by means of hickory specimens, on the other hand, no glue has any bond quality (in terms of per cent wood failure) until point *D* is reached, in spite of the fact that on the basis of the cedar specimens it has been recording 100 per cent bond quality from point *B* to point *D*.

If this interpretation of the interrelationship between wood failure, species, and glue strength is acceptable, then it must follow that wood failure by itself is not sufficient to describe bond quality. The percentage of wood failure should be qualified by the species to which it refers.

Wood to Wood Bonds with Epoxide Resins—Species Effect[1]

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The quality of the bond is determined by the resin formulation used. Only two of the epoxy formulations were satisfactory with stronger woods, although all three could be used with low-strength wood. The resins were not water resistant when cured at room temperatures, but water resistance was improved by curing at an elevated temperature.

EPOXIDE RESIN ADHESIVES are relatively new, but epoxide compounds were first observed in 1863 by Wurtz. Later, in 1891, Lindeman made some resinous substances from the reaction products described by Wurtz. Scientists at the I. G. Farbenindustrie studied the reactions of epoxides with poly-amines in the early 1930's and secured several patents from their research. At that time, they pointed out the possibility of using epoxy compounds as a base for adhesives (11)[2]. In 1947, Ciba in Switzerland, and Devoe and Raynolds in the United States, developed a successful epoxy adhesive (23). They have since licensed other companies to manufacture these compounds, and at present there are several prime producers of epoxy resin in this country.

Epoxy resins are compounds in which the molecular structure contains oxygen linked in a chain of carbon atoms to two of these atoms. Below is the proposed formula for an epoxy resin (28).

Epoxides are prepared by reacting compounds containing epoxide groups, that is, $\underset{O}{\overset{\frown}{C-C}}$, with polyfunctional alcohols or phenols. Today they are prepared commercially by reacting epichlorohydrin with bisphenol-A. The excess of epichlorohydrin present effects the value of n in the formula for the epoxy resin molecule. This value of n determines the molecular weight, as well as the physical state of the resin.

To be used as an adhesive, either an acidic or basic curing agent must be added to further cross link the resin molecule into an infusible and insoluble solid. Generally, amine curing agents are used. The particular curing agent used determines the final physical properties of the cured resin (13). Brittle or rigid bonds, caused by excessive cross linking of the resin, can be overcome by the addition of a plasticizer such as Thiokol (4) or a polysulfide (22). The desired adhesive properties are obtained by varying the formulation of the adhesive.

The cured resin contains carbon-to-carbon and ether linkages, which account for the strength and stability of the resulting bond (11). The epoxy and hydroxyl groups are the source of the good adhesive properties of the resin (21). McLaren's studies (18) show that compounds with hydroxyl bonding groups have a great affinity for cellulose; therefore, since this resin has both the epoxy and hydroxyl groups in the same molecule, it appears to have the potentiality of being an excellent wood adhesive.

Epoxy adhesives are rated as excellent in resistance to chemicals, solvents, heat, cold, and fungus attack. The effectiveness of the bond formed with wood, metal, rubber, glass, paper, textile, and ceramic also is classified as excellent. Other desirable properties of epoxy adhesives are low shrinkage on curing, room-temperature and contact-pressure bonding, and absence of by-product formation on curing (1)

Nearly all the epoxy adhesives manufactured today are for use in metal, plastic, or ceramic bonding. They have not as yet been considered seriously by the wood industries, principally because of cost. The price of epoxy resin produced in the United States in 1955 ranged from 59 cents to $1.34 per pound as compared to 25 cents per pound for a straight phenolic resin (3). The price barrier is not a permanent obstacle, however. Current research in the industry has indicated at least one possibility of producing these materials as a by-product in the production of acetic acid. This and similar developments should lead to increased production at a lower cost.

A reduction in price would not make these adhesives acceptable to the wood-using industries without knowledge of their wood-bonding properties and the factors which affect these properties. Adhesive formulators have made numerous statements to the effect that epoxide resins will successfully bond wood. These statements are not substantiated by published, experimental data to date.

The only published information concerning the results obtained with epoxy adhesives and wood is that presented by Clarke (8). He noted the effect of various factors on the bond strength. The results of Clarke's experiments, which are limited to a single epoxy resin formulation, may be summarized as follows:

1. Curing temperature is the most important factor in determining the shear strength and wood failure of the resulting glue line
2. A low-temperature-cured glue line will continue to cure with aging.
3. Rate of spread does not affect the strength of the bond.
4. The assembly time has no effect on the bond strength.
5. The bonds were not water resistant.

[1] Authorized for publication in the Journal Series of the Pennsylvania Agricultural Experiment Station as Paper No. 2201, October, 1957.

[2] Numbers in parentheses refer to the Literature Cited at the end of the paper.

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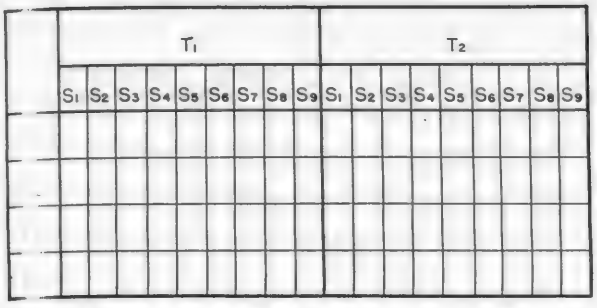
T1
T2
S1 S2 S3 S4 S5 S6 S7 S8 S9
S1 = RED OAK
S2 = WHITE OAK
S3 = HARD MAPLE
S4 = YELLOW POPLAR
S5 = DOUGLAS FIR
S6 = SOUTHERN YELLOW PINE
S7 = SPRUCE
S8 = REDWOOD
S9 = LIGNUM VITAE
T1 = 70° F
T2 = 160° F
EPOXY ERL 3794 VERSAMID 125
EPOXY ERL 3794 ZZL 0812
EPOXY ERL 3794 ERL 2793
RESORCINOL G1124-A G1124-B

Fig. 1.—Experimental design.

Table 1.—PHYSICAL PROPERTIES OF BASE RESIN AND HARDENING AGENTS

	Base Resin	Hardeners		
	ERL 3794	ERL 2793	ZZL 0812	Versamid[1]
Specific gravity	1.2	1.06–1.09	.965–.975	...
Viscosity, cps.	7,200–19,200	5,000–13,000	30–40	...
Amine assay (per cent)	...	49–52	15.5–16	...
Epoxy assay (grams 1 gramole epoxy)	170–182	...	...	...
Parts hardner per 100 parts resin	...	25	22.5	100

[1]Polyamide resin; product of General Mills, Inc.

6. The wood failure obtained with this resin was characteristically low under all combinations of temperature, spread, and assembly time included in the experiment.

An unpublished paper by Frank (12) notes that, in shear-block tests with oak and maple wood, the epoxy resin gave higher strength values with oak than with maple, whereas a resorcinol produced stronger bonds with the maple than it did with the oak. On the basis of these results, Frank suggests that epoxide resins may produce better bonds with some species of wood than with others.

Previous studies have been made to observe the effect of species on wood-to-wood bonds. One of the earliest was that of Truax (25) in 1929. He reported that there were characteristic variations in the gluing properties among species when bonded with the various natural wood adhesives then in use. Kitazawa (14), in 1946, made a microscopic study of the glue lines of 22 native woods bonded with resorcinol and urea-formaldehyde resin adhesives. He concluded that the total adhesion may be correlated to the nature of the pore surface, which in turn reflects species variation. The species effect of tropical woods on phenol and phenol-resorcinol resin adhesive bonds was reported by Troop and Wangaard (24). They noted that all species tested could be bonded, but some were more easily and successfully joined than others. A recent review of species effect was made by Eickner (10) at the Forest Products Laboratory in 1955. Eickner compared the gluing properties of 15 native woods with a cold-setting urea resin adhesive.

Information regarding the effect of species on epoxy resin bonds is a necessary part of the development of the over-all pattern of the factors that determine the usefulness of this type of adhesive. It was the purpose of this study to observe the relationship of wood species to the effectiveness of an epoxy adhesive wood-to-wood bond. The effectiveness of the bond was measured as the load it is capable of sustaining in tension perpendicular to the glue line.

Procedure

Design of Experiment: The experimental design followed in carrying out this study is shown in Fig. 1. Within its framework are included four adhesives, two curing temperatures, and nine species. Each combination of adhesive, temperature, and species is replicated five times.

A Bakelite C-8 epoxy resin, ERL 3794, was used as a base resin in this experiment. Since the final properties of the cured resin depend on the curing agent, three different hardeners were used in formulating the epoxy resin. The three curing agents used were Versamid 125, ERL 2793, and ZZL 0812. The physical properties of the resins used, as stated by the manufacturer, are listed in Table 1 (2).

A control group of specimens, made with a resorcinol resin (Koppers' Penacolite G1124-A), was included in order to observe the strength values obtained for the various species with the cross-lap test specimen and a standard, commercial wood adhesive.

The epoxide adhesives were formulated as room-temperature (70° F.) curing resins. However, these adhesives can be cured at elevated temperatures to shorten the length of cure and, in some instances, this results in an improvement in the properties of the cured resin. Clarke (8) found that an increase in dry-bond shear strength between maple laminae could be obtained if a similar adhesive were cured at temperatures up to 160° F. It was decided, therefore, to compare the results obtained with this resin when cured at room temperature and at 160° F.

The species of woods tested are listed in Fig. 1. These include four coniferous and four deciduous species that are bonded in various commercial applications today. The lignum vitae, a tropical hardwood, was included to observe whether the epoxy adhesive could successfully bond a wood containing large quantities of oily extractives. Present commercial wood adhesives will not bond this wood without prior treatment to remove the extractive material (24, 25). The variety of species chosen covers a wide range of wood structure and specific gravity.

A cross-lap test specimen such as that described by Marra (15, 16, 17) was used throughout this study. This type of specimen measures the tensile strength of the bond, and is similar to that used in the glass industry for testing adhesives (19). DeBruyne (9) and Blomquist (7) have each advanced theories that tensile forces are involved in most actual bonding situations, and since the tensile strength of the adhesive is less than its shear strength, this is the more appropriate specimen to use in adhesive evaluation. A preliminary experiment made in conjunction with this project showed that the cross-lap specimen detected variation in the qualities of adhesives, as well as did the standard shear-block specimens. Further proof of its sensitivity and reliability is provided by Marra's studies (15, 16, 17).

Besides being a reliable and sensitive means of detecting variations in bond strength, the cross-lap specimen has other advantages in that the specimens are easy to prepare, each specimen has a limited and thus uniform contact surface, only moderate test loads are required, and variations in test procedure such as a change in the rate of loading do not affect the strength values obtained. Among the disadvantages of using this specimen are its sensitivity to moisture-content changes because of the large areas of

end grain present, its lack of sensitivity to flaws in the center of the bonding area, the bending of the specimen during testing, which may induce differential stresses, and the necessity of removing the fillets formed by the adhesive squeeze-out prior to test.

A testing tool for cross-lap specimens was adapted for use with a Tinus Olsen universal testing machine. The lower test grip was mounted on a half-round bearing block, which formed a semi-rigid set of testing grips. The head of the testing machine was lowered, thus transmitting a tensile load to the specimen at the glue line. The load was applied at a rate of 0.05 inch per minute, and the maximum load was recorded along with the area of wood failure.

Results and Analysis

Bond Strength: The average strength values for the various combinations of woods, adhesives, and curing temperatures are shown in Table 2.

Originally, it was proposed to examine the data of Table 2 by a single analysis of variance, but when the species variation was tested for homogeneity, it proved to be heterogeneous (6). Because of this, the data for each species were evaluated separately. Table 3 is a summary of the individual analyses of variance for species.

To interpret the data in Table 3 it is necessary to point out the restrictions that apply under the conditions of this experiment (5). In this study, the adhesives were not considered as samples from an infinite population but as the entire population of adhesives. Since the two temperatures were chosen from a continuously varying scale, they were considered as samples from an infinite population of temperatures. Under these conditions, the mean square for adhesives and for temperature-adhesive interaction was tested against the within-replication mean square, which is the error variance. The mean square for temperature, however, was tested against the interaction mean square.

When this procedure is followed, a significant *F* value for adhesives indicates that there is a difference in strength among the adhesives studied, but that this conclusion can not be extended beyond the species and adhesives considered. A significant *F* value for temperature may be interpreted as implying that, regardless of the adhesives used, there is an average difference in strength within a species that may be attributed to the effect of temperature. A significant *F* value for the temperature-adhesive interaction indicates that the magnitude of the difference between adhesives is influenced by the curing temperature.

Table 2.—AVERAGE BOND STRENGTH WITHIN SPECIES (PSI)[1]

Adhesive	Curing temp. (°F)	Red oak	White oak	Hard maple	Yellow poplar	Douglas fir	Southern yellow pine	Spruce	Redwood	Lignum vitae
Epoxy ERL 3794 Versamid 125	70	30.13	69.00	13.80	10.33	199.60	63.20	262.73	163.60	39.87
	160	295.50	185.27	60.87	272.87	186.60	71.87	228.53	180.80	31.92
Epoxy ERL 3794 ZZL 0812	70	388.87	380.67	308.93	350.20	270.73	200.20	301.73	206.73	65.60
	160	270.67	247.47	176.00	379.87	144.13	282.67	295.20	193.80	101.07
Epoxy ERL 3794 ERL 2793	70	353.07	389.73	225.40	368.33	198.20	334.73	286.07	179.73	68.67
	160	366.13	236.73	259.40	294.07	140.80	306.34	125.53	164.53	61.40
Resorcinol G1124-A G1124-B	70	479.80	377.33	571.33	460.00	220.25	346.73	252.67	221.60	89.00
	160	413.53	354.34	334.80	295.93	138.58	325.07	248.46	192.46	70.27

[1]PSI was computed as total load divided by a constant (3), thus it is a coded value for total load rather than stress.

All the species showed a significant difference in bond strength due to adhesives. The effect of curing temperature was not significant. The temperature-adhesive interaction was significant for all species except redwood.

Although Table 3 indicates the presence of significant differences in bond strength due to adhesives and to a temperature-adhesive interaction, it does not indicate where these differences exist. To differentiate more precisely

Table 3.—ANALYSIS OF VARIANCE OF EFFECT OF ADHESIVES AND CURING TEMPERATURES ON THE TENSILE STRENGTH WITHIN SPECIES

Source of variation	Degrees of freedom	Sum of squares	Mean square	F ratio
Red oak				
Adhesive (G)	3	423,257.39	141,085.75	44.84**[1]
Temperature (T)	1	5,518.51	5,518.51	NS
G x T	3	216,868.48	72,289.49	22.98**
Within Groups	32	100,675.11	3,146.09	
Total	39	746,319.49	19,136.40	
White oak				
Adhesive (G)	3	315,584.91	105,194.97	47.04**
Temperature (T)	1	5,397.73	5,397.73	NS
G x T	3	81,097.40	27,032.46	12.08**
Within groups	32	71,564.54	2,236.39	
Total	39	473,644.58	12,144.73	
Hard maple				
Adhesive (G)	3	863,409.50	287,803.16	107.30**
Temperature (T)	1	51,840.72	51,840.72	NS
G x T	3	140,168.71	46,722.90	17.41**
Within groups	32	85,834.24	2,682.32	
Total	39	1,141,253.17	29,262.90	
Yellow poplar				
Adhesive (G)	3	360,169.00	120,656.33	131.69**
Temperature (T)	1	2,093.09	2,093.09	NS
G x T	3	250,257.15	83,419.05	91.50**
Within groups	32	29,172.78	911.65	
Total	39	641,692.02	16,453.64	
Douglas-fir				
Adhesive (G)	3	8,173.61	2,724.54	4.79**
Temperature (T)	1	48,569.05	48,569.05	NS
G x T	3	16,840.24	5,613.41	9.87**
Within groups	32	18,186.00	568.31	
Total	39	91,768.96	2,353.05	
Southern yellow pine				
Adhesive (G)	3	454,218.16	151,406.05	115.00**
Temperature (T)	1	1,054.01	1,054.01	NS
G x T	3	19,324.85	6,441.62	4.91**
Within groups	32	42,005.78	1,312.68	
Total	39	516,602.80	13,246.22	
Spruce				
Adhesive (G)	3	48,141.01	16,047.00	20.37**
Temperature (T)	1	26,387.23	26,387.23	NS
G x T	3	36,193.08	12,064.36	15.32**
Within groups	32	25,206.06	787.69	
Total	39	135,927.38	3,485.31	
Redwood				
Adhesive (G)	3	10,136.32	3,378.77	4.73**
Temperature (T)	1	1,003.70	1,003.70	NS
G x T	3	2,858.27	952.76	NS
Within groups	32	22,861.24	714.41	
Total	39	36,859.53	586.19	
Lignum vitae				
Adhesive (G)	3	99,276.08	33,092.03	54.05**
Temperature (T)	1	20,591.62	20,591.62	NS
G x T	3	47,859.49	15,953.16	26.05**
Within groups	32	19,591.84	612.22	
Total	39	187,319.03	4,803.05	

[1]NS Not significant at 5 per cent level.
**Significant at 1 per cent level.

Table 4.—TEMPERATURE–ADHESIVE COMBINATIONS RANKED BY STRENGTH WITHIN SPECIES

Temperature: T1— 70°F. T2— 160°F. Adhesives: G1—ERL 3794/Versamid 125 G2—ERL 3794/ZZL 0812 G3—ERL 3794/2793 G4—G1124-A/G1124-B

Group	Red oak	White oak	Hard maple	Yellow poplar	Douglas-fir	Southern yellow pine	Spruce	Redwood	Lignum vitae
	T1G4 T2G4	T1G2 T1G4 T2G4	T1G4	T1G4	T1G2	T2G4 T1G4 T1G3	T1G2 T2G2 T1G3 T1G1 T1G4 T2G4	T1G4 T1G2 T2G2 T2G4 T2G1 T1G3	T2G4
I	T1G2 T2G3 T1G3 T2G1	T1G3 T2G2 T2G3	T2G4 T1G2 T1G3 T2G3	T2G2 T1G3 T1G2	T1G4 T1G1 T1G3 T2G1	T2G3 T2G2	-----	- -	T2G2 T1G4 T1G3 T1G2 T2G3
II	T2G2	T2G1	T2G2	T2G4 T2G3 T2G1	-----	T1G2	T2G1	-	- ---
I	T1G1	T1G1	T2G1 T1G1	T1G1	T2G2 T2G3 T2G4	T2G1 T1G1	T2G3	T2G3 T1G1	T1G1 T2G1

the relative merit of the various temperature-adhesive combinations within each species, the strength values listed in Table 2 were ranked in descending order and separated into groups as shown in Table 4.

These groups were formed according to the Studentized range at the 5 per cent probability level (5). Starting with the highest strength value within a given species, differences were computed between it and successive values until a difference was found that was significant. A separation was made at this point. On this basis, all the temperature and adhesive combinations within a group may be considered as performing equally well in that their over-all strength values are not significantly different from one another. This type of grouping does not imply that the highest value of a group is significantly different from the lowest value of the group immediately preceding it. With the exception of Douglas-fir, spruce, and redwood, the temperature-adhesive combinations separated into four distinct groups. In the case of species where there were less than four groups, the temperature-adhesive combinations that fell below Group I were placed in a position that most appropriately expressed their relative merits. In redwood, for example, which separated into only two groups, the temperature-adhesive combinations T2G3 and T1G1 gave the lowest strength values within this species, and hence were placed in Group IV.

Although Table 4 may not be used to make direct comparisons of bond strength between species, it can serve as a basis for comment regarding the over-all performance of the adhesives and the effect of temperature on the glue-line strength attained by a given adhesive within a particular species.

Of the adhesives studied, the resorcinol cured at either 70° F. or 160° F. appears in Group I for all species except Douglas-fir, and hence must be considered an excellent adhesive for all the species listed. The epoxy resin with the Versamid hardener cured at room temperature is found in Group IV for all species with the exception of Douglas-fir, where it appears in Group II, and spruce, where it appears in Group I. This adhesive formulation cured at room temperature is the least promising of the epoxides. The other two epoxide formulations appear somewhere between these extremes, with some indication that formulation G2 gives a better over-all performance than does G3.

In general, the most clear-cut separation among the glues is to be found in those species such as red oak, white oak, and maple, which have the highest inherent strength in tension perpendicular to the grain. The inconsistency that exists between the type of separation found in Douglas-fir and spruce, two woods whose strength in tension is essentially equal, must be attributed to other causes. Redwood has the lowest strength in tension perpendicular to the grain of all the woods studied, and the information in Table 4 indicates that the majority of the adhesives tested are capable of developing the full strength of this wood.

Comments as to the effect of temperature on a particular adhesive within the various species will be limited to the epoxy formulations. A significant increase in strength of the epoxy/Versamid was brought about by an increase in curing temperature for red oak, white oak, yellow poplar, and redwood. In general, a heat cure improved epoxy/Versamid.

An increase in curing temperature of epoxy formulation G2 caused a decrease in bond strength in red oak, white oak, hard maple, and Douglas-fir, no significant difference in yellow poplar, spruce, and redwood, and a significant increase in southern yellow pine. In general, a heat cure reduced the strength of a bond formed with epoxy formulation G2.

An increase in curing temperature used with epoxy formulation G3 caused no significant difference in bond strength in red oak, white oak, and hard maple, and a significant decrease in bond strength in yellow poplar, Douglas-fir, southern yellow pine, spruce, and redwood. There is no indication of an increase in the bond strength of G3 with an increase in curing temperature, and ample evidence that an elevated temperature produces a bond that is generally inferior.

Wood Failure: The average wood failures for each individual combination of species, adhesive, and curing temperature are recorded in Table 5 in a manner similar to that used for recording the bond strengths.

The average wood failure values presented in Table 5 were subjected to a range analysis within species and within adhesives. The analysis within species was accomplished by summing the average wood failures for the eight temperature-adhesive combinations and obtaining the over-all range within each species. The species were then listed in descending order of total wood failure and ranked at a 5 per cent probability level by use of a table of critical factors for range analysis

Table 5.—AVERAGE WOOD FAILURE WITHIN SPECIES (PER CENT)

Adhesive	Curing temp. (°F)	Red oak	White oak	Hard maple	Yellow poplar	Douglas-fir	Southern yellow pine	Spruce	Redwood	Lignum vitae
Epoxy ERL 3794 Versamid 125	70	0	0	0	0	79.0	0.4	57.0	91.0	0
	160	24.0	0.4	0.4	82.0	73.0	4.4	60.0	97.8	0
Epoxy ERL 3794 ZZL 0812	70	5.8	19.0	2.4	31.0	87.0	1.0	89.0	96.2	0
	160	12.0	3.0	.8	79.0	46.0	28.0	40.0	95.0	0
Epo ERL 3794 ER 2793	70	2.8	6.4	0	44.0	92.8	13.8	76.0	98.2	0
	160	41.0	2.6	15.6	95.2	46.0	29.0	42.0	95.0	0
Resorcinol G11 -A G11 -B	70	5.2	11.4	18.4	16.2	68.0	28.0	18.0	92.0	0
	160	50.0	10.8	9.4	79.0	74.0	17.4	54.0	96.2	10.0

Table 6.—SPECIES RANKED BY WOOD FAILURE

Group	Species	Summation of average wood failures (Per cent)
I	Redwood	761.4[1]
II	Douglas-fir	565.8
III	Spruce	436.0
	Yellow poplar	426.0
IV	Red oak	140.6
	Southern yellow pine	122.0
	White oak	53.6
	Hard maple	47.0
	Lignum vitae	10.0

[1]Maximum possible wood failure: 800 per cent.

(6). The species ranked by wood failure are shown in Table 6.

All species within the same group may be considered as having equal amounts of wood failure. A similar procedure was used to rank the wood failures by adhesives, but this showed that there were no significant differences among the wood failures within adhesives. The wood failures obtained appeared to be dependent upon the inherent properties of the individual species rather than on the particular adhesives used. This is evident from Table 5, which shows that some species had high wood failures with all temperature-adhesive combinations, whereas others produced uniformly low wood-failure values.

In determining the relative strength of a group of adhesives on the basis of a series of mechanical tests employing wood as an adherend, the possibility exists that an adhesive will exhibit low bond strength simply because it was combined with an adherend that was inherently weak. An evaluation of the amount of wood failure is used as a means of judging whether or not such an occurrence took place. In the over-all evaluation of the adhesives used in this study, the fact that these materials were used with woods that have a wide range of strength properties minimizes this effect. There still remains the possibility that, within a species, a particular adhesive appears in a low-strength group as in Table 4 merely because it was combined with low-strength material. The information in Tables 5 and 6 provides a means for judging whether or not this took place.

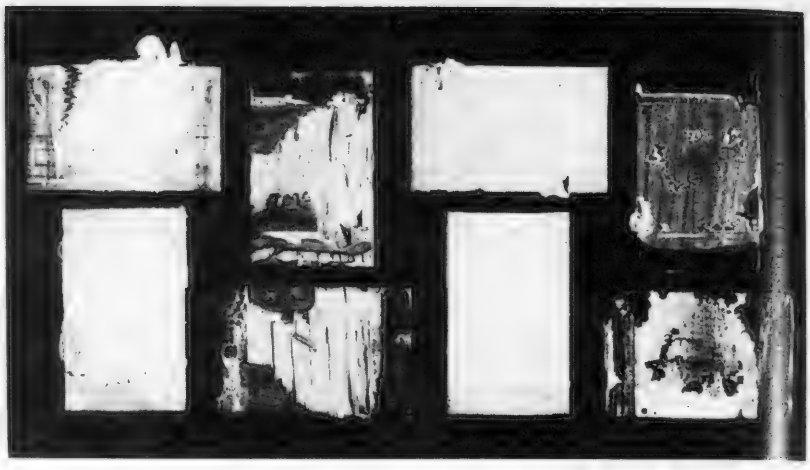

Fig. 2.—Typical wood failures of specimens cured at 70° F. Left to right: spruce, redwood, hard maple, lignum vitae.

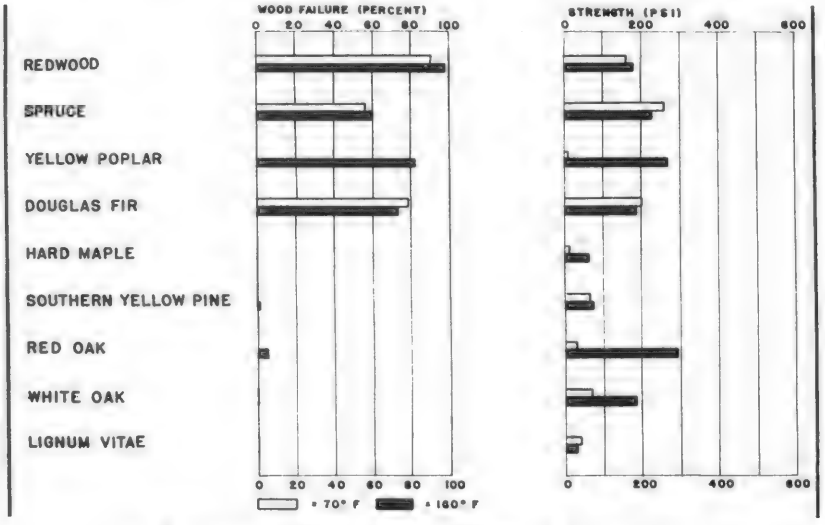

Fig. 3.—Maximum strength and wood failure for the formulation, epoxy/Versamid 125.

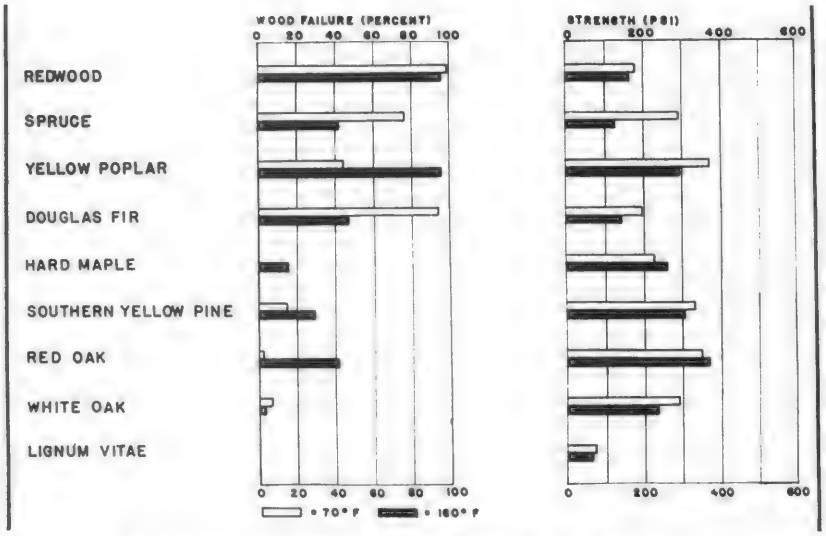

Fig. 4.—Maximum strength and wood failure for the formulation, epoxy/ERL 2793.

Redwood has an average wood failure that is significantly higher than that of any of the other species tested. Wood failure within this species is quite consistent, regardless of the temperature-adhesive combination used. Therefore, it may be concluded that in general the bond strengths of all the adhesives tested were limited to the same degree by the strength of the wood. The species in Group IV of Table 6 had wood failures that were significantly lower than those of the other species tested. Within this group there was no combination of adhesive, temperature, and species that had an average wood failure of more than 50 per cent. This would indicate that the bond strengths reported for these species are not influenced by variation of the wood strength within a species.

Douglas-fir falls in Group II of Table 6. The wood failure in this species is subject to considerable variation due to the effect of grain orientation. Group III occupies an intermediate position in Table 6, and the two species within this group show quite different patterns. Reference to Tables 4 and 5 shows that, with spruce, high bond strengths and high wood failures occur with the same temperature-adhesive combinations. This is a strong indication that the ranking of the temperature-adhesive combinations

spruce in Table 4 are valid. In the case of yellow poplar, there are temperature-adhesive combinations that give high bond strengths with low wood failure, as well as combinations that give low bond strengths with high wood failure. Under these conditions, there is reason to believe that the adhesives with low bond strength and high wood failures appear in a lower group in Table 4 than is warranted by their strength in either adhesion or cohesion.

Relationship Between Bond Strength and Wood Failure: To continue the evaluation of these data, it is necessary to reconsider the objectives of testing adhesive bonds. The first thing to consider is what the observed strength values are actually measuring. Strength values may be limited by the strength of the adhesive, strength of the interface, or the strength of the wood. From close observations of the wood failure, it is possible in some instances to determine which of these three factors limited the bond strength. If the failure appeared entirely within the adhesive, which would be indicated by the presence of an adhesive film on each surface after fracture of the specimen, it could be stated that the cohesive strength of the glue had been reached before the adhesive strength of the bond and, therefore, the actual bond strength is unknown.

In a situation where the specimen separated at the interface between the adhesive and the wood, the failure was due to the lack of adhesion by the adhesive. This would be an accurate measurement of the adhesive's bonding ability. An example of this nature would not have any wood failure, and the adhesive layer would be on one surface only or separated from both surfaces. If the strength achieved by the adhesive, both in cohesion and adhesion, is greater than the strength of the wood, then there would be close to 100 per cent wood failure at the interface. Thus, it was the strength of the wood and not that of the adhesive which had been measured.

In most instances, it is not possible to determine which of the three limiting factors are involved in the failure of a specimen, because the failure is often a combination of all these factors. Occasionally, however, examples appear where the limiting factor is apparent. The lignum vitae specimen shown in Fig. 2 is an example where the interface was the limiting factor, as illustrated by the glue film that has remained intact though separated from both surfaces. The maple specimen in Fig. 2 could have been limited either by failure of cohesion in the glue or adhesion at the interface; however, it definitely was not limited by the strength of the wood. Wood failure was the limiting factor in the strength values obtained with the redwood and spruce.

After the limiting factors are considered, the quantitative accuracy of the observed strength values must be decided. This can be evaluated in a manner similar to that used by Reinhart (20) to describe the variation between observed and theoretical strength values obtained by various adhesive-testing procedures. In this study, the maximum theoretical value obtainable was the strength of the particular species in tension perpendicular to the grain.

There were inherent stress concentrations within the test specimen which prevented the observed values from equaling the theoretical values, however. These maximum possible strength values within each species were further limited by the adhesive's ability to adhere to the wood. If an observed strength value were near that of the wood, it could be assumed that the particular adhesive was capable of adhering successfully to the wood, and the difference in strength values may be attributed mostly to stress concentrations inherent in the specimen. Since the same type of specimen was used throughout the experiment, the reduction in strength of the bond from that of the wood due to the type of specimen was considered uniform. Therefore, where the strengths obtained were far below those of the wood in tension, the reduction was considered to be due to the bonding properties of the adhesives.

In general, the coniferous species more nearly approached the published strength values than did the denser deciduous woods. Considering only the native species in the experiment, the oak bonds were the farthest from the published wood strength, and the redwood bonds were nearest to the pub-

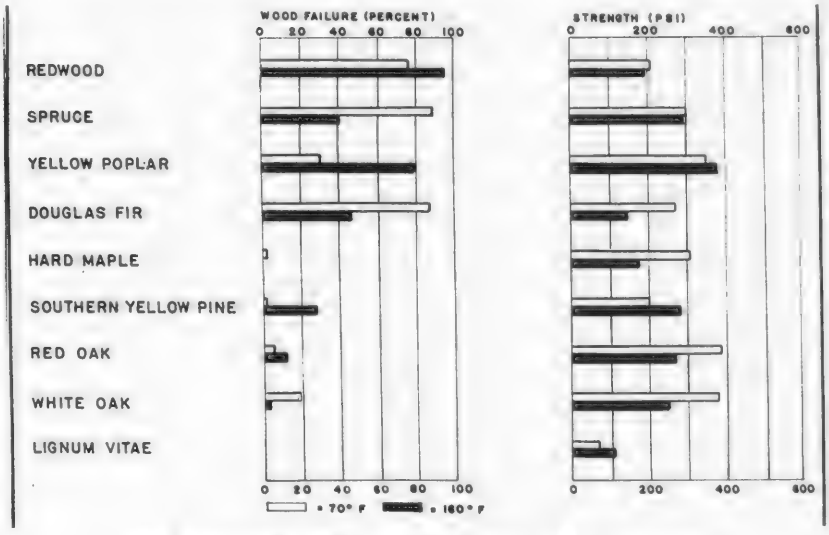

Fig. 5.—Maximum strength and wood failure for the formulation, epoxy/ZZL 0812.

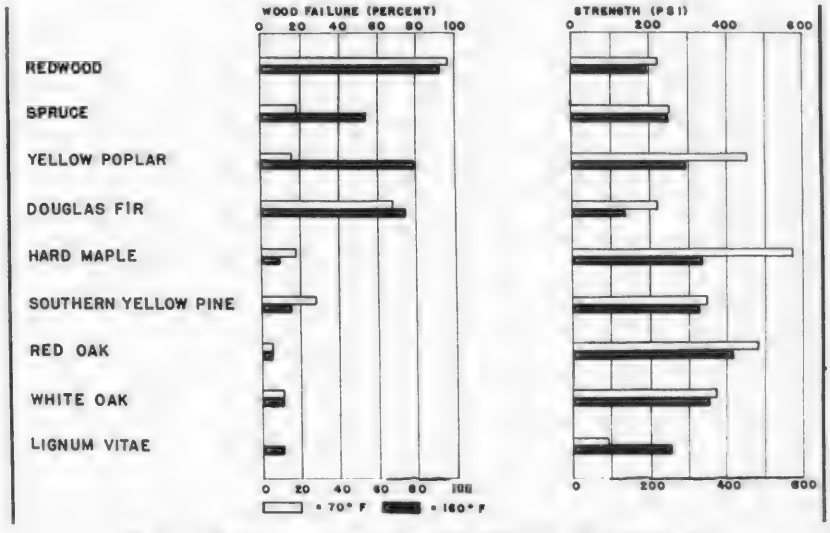

Fig. 6.—Maximum strength and wood failure for the formulation, resorcinol/G1124-B.

lished values. From this it may be concluded that there was a relatively small reduction due to the form of the specimen as demonstrated in the redwood, and that the adhesives' bonding ability was the principal cause for the lower values obtained.

No mechanical means of testing has been devised that accurately measures the maximum strength of an adhesive bond, but these tests provide a criteria by which to compare the qualitative values of adhesives for practical applications. This study presents some indication of the strengths to be expected under prescribed conditions with these four adhesive formulations and nine species of wood. By comparing the bond strengths obtained and the amount of wood failure accompanying them, a proper adhesive formulation may be selected for a given species.

The relationships between wood failure and bond strength for each adhesive, species, and curing temperature are summarized in Figs. 3, 4, 5, and 6.

Water Resistance: The strengths achieved with any adhesive are not the only criteria by which adhesives are evaluated. The strongest bonds may prove to be useless in some situations if they are not water resistant. Therefore, an additional series of tests was conducted to survey the water-resistant qualities of the adhesives used in this study.

A preliminary test with red oak and the four adhesives showed that the epoxy adhesives were not water resistant when cured at room temperature. They all delaminated within three days after being submerged in water. The room-temperature-cured resorcinol adhesive did not delaminate. When a similar test was made with the epoxides cured at an elevated temperature, only the epoxy hardened with Versamid delaminated.

A more complete experiment was conducted with cross-lap specimens that had been cured at 160° F. All species except lignum vitae were included in this test. Due to time limitations, only one cycle was completed and that consisted of a 15-day soaking followed by a drying period of 10 days. The specimens were soaked in tap water at room temperature, and the drying was done over a blower-powered heating register, thus insuring a rapid air circulation around the specimens.

The epoxy formulated with Versamid delaminated in less than a week with all but one species, redwood. The maple and white oak specimens made with the ZZL 0812 cured resin delaminated during the soaking period. Only the maple specimen in the ERL 2793 heat-cured series delaminated. None of the specimens bonded with resorcinol resin delaminated. There were no other delaminations after the drying cycle was completed.

While these tests were not extensive enough to make concise statements about the water-resistant qualities of the adhesives, they are sufficient to indicate generalized observations. The epoxy formulations did not approach the water resistance of the resorcinol resin when cured at room temperature. Heat curing did not make these epoxy adhesives water proof, but it did improve their water-resisting qualities. The Versamid-epoxy formulation was the least water resistant of the formulations tested, and the water resistance was not improved by increasing the curing temperature. This formulation did form a water-resistant bond with redwood, however, which indicates some compatability of the wood with this resin. The other two epoxy formulations gave results nearly equal to the resorcinol adhesive when cured at 160° F.

Conclusions

The following conclusions may be drawn from the results of this experiment:

1. Of the three epoxy formulations tested, only two are considered suitable as potential adhesives. They are the formulations made with the hardeners ERL 2793 and ZZL 0812. The epoxy resin cured with Versamid 125 did not prove to be suitable for use as a wood adhesive.

2. There is no well-defined species preference among these adhesives when used to bond woods of high strength. Redwood, a low-strength species, is a possible exception as evidenced by the uniformly high dry bond strength obtained with all the epoxy formulations, as well as the water resistance exhibited by the epoxides when used with this species.

3. An increase in the curing temperature does not cause a significant improvement in the bond strength obtained with the epoxy formulations used. In some instances, the bond strengths of these epoxy formulations decreased as a result of an increase in curing temperature.

4. These three formulations are not water resistant when cured at room temperature, but the water resistance of the bond is improved with an increase in the curing temperature.

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The Extraneous Components of Western Red Cedar[1]

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Extraneous materials were a complex mixture, and ranged from 5 to 25 per cent of the weight of the wood. Thujaplicins, methyl thujate, thujic acid, hydroxythujaplicin, arabinose, placatic acid, several uncharacterized phenols, and a plant sterol have been isolated. The nature of these chemicals and how they account for several characteristic properties of the species is explained.

THE COMPOSITION OF THE EXTRANEOUS COMPONENT fraction of wood varies widely from one species to another, and a great variety of chemical substances may be encountered. While these substances, also known as extractives, do not contribute to the wood structure, their presence in minor amounts usually accounts for the characteristic properties such as color, taste, odor, and durability by which we recognize the various species.

In some cases, because of special properties, these substances although present in very small proportion profoundly affect the way in which a wood may be utilized. For example, the presence of less than 1 per cent of pinosylvin (a phenolic substance) prevents the successful pulping of pine heartwood by the calcium base sulphite process. In other cases, minor components have proved to be valuable industrial chemicals and their presence has led to profitable diversification, as for instance, in the production of tall oil as a by-product in the sulphate pulping of southern pines. In others, a knowledge of the extraneous components has provided data contributing to the taxonomic classification of the species and sometimes has stimulated research in new fields of organic chemistry by the discovery of compounds of novel types.

Western red cedar, a major species in British Columbia and the Pacific Northwest and well known for its natural durability, has a high content of extraneous materials, the proportion frequently exceeding 20 per cent in the outer butt heartwood. In the conversion of cedar to lumber and shingles, large volumes of mill residues are produced. The problem of finding adequate outlets for these residues and the logs classed as cull for lumber purposes is a difficult one. In contrast to other species such as fir and hemlock, there has been little demand for chipped cedar mill residues for kraft pulping purposes. A low yield per digester is obtained because of the low wood density, and increased digester corrosion is encountered unless special linings are installed.

To provide a detailed knowledge of the chemistry of the extraneous component that would be useful in improving the utilization of cedar, an investigation was begun by the Vancouver Laboratory of the Forest Products Laboratories of Canada. This paper outlines the present knowledge of the extraneous component that has resulted from this investigation and previous work by others.

The Volatile Oil

Perhaps the most interesting chemicals found in cedar from the biological and chemical point of view are the steam-volatile thujaplicins, the simplest known naturally occurring tropolones. The tropolones are a class of organic compounds that were first recognized as such in 1945 (6)[3]. They possess unusual and characteristic properties by virtue of their triply unsaturated seven-membered carbon ring structure with a carbonyl and hydroxyl group in neighboring positions on the ring. The thujaplicins are tropolones with an isopropyl group substituted on the ring, and depending on where this group is relative to the carbonyl and hydroxyl groups, are known as the α, β and γ isomers (I, II and III). All three of these isomers occur in western red cedar (12, 2, 10), with the β, and γ predominating and α present only in relatively minor amounts.

The thujaplicins are highly toxic to wood destroying fungi, the toxicity being of the same order as that of so-

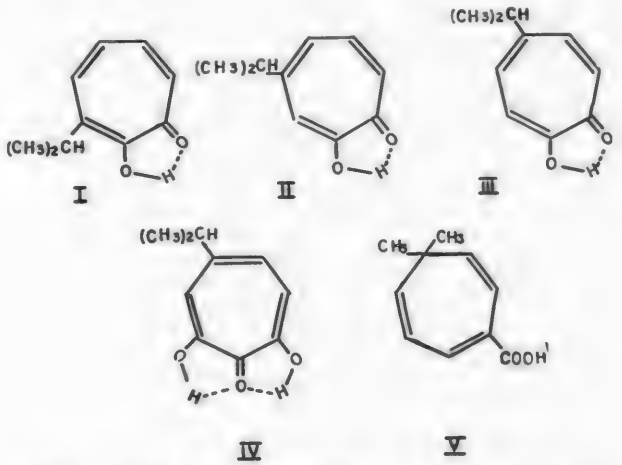

Fig. 1.—Some of the volatile components of the extraneous material in western red cedar: I, α thujaplicin (3-isopropyltropolone); II, β thujaplicin (4-isopropyltropolone); III, γ thujaplicin (5-isopropyltropolone); IV, 7-hydroxy-4-isopropyltropolone; and V, thujic acid.

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[2] A Division of the Forestry Branch, Department of Northern Affairs and National Resources.

[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

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dium pentachlorphenate (18). Because of the obvious connection between the presence of these highly potent natural preservatives in the wood and the high natural durability of western red cedar, an accurate method of analyzing small wood samples for thujaplicin content was developed. The method was used to determine the natural variations in content which occur in cedar wood. Details of the method and the results obtained therewith have been published elsewhere (14, 15, 16). No thujaplicin was detectable in the sapwood. Wide variations were found in the heartwood. Within trees, a general pattern of increase from inner to outer heartwood and of decrease with increasing distance of the sample up the tree was encountered. In young trees, the content was low and in the same range as that in the inner wood of mature trees, the portion representing their early growth period. Apparently as a tree matures, its ability to manufacture fungicidal extractives is increased with the result that newly formed heartwood has the greatest content. Superimposed upon the pattern of radial increase is a marked dependence on color. In cross-sections exhibiting characteristic color variations from light straw to various shades of brown, the lighter colored wood invariably had a higher content of thujaplicins than the dark-colored wood immediately adjacent to it. The pattern of decay in cedar in nature and in accelerated testing corroborates these chemical findings (8, 5, 7).

In the butts of mature trees, the content of thujaplicin may range from zero at the pith to as high as 1.2 per cent in the outer straw-colored heartwood. Since in present extensive shingle manufacturing operations on the west coast a substantial proportion of the mill residue consists of solid "spalts" of this outer light-colored butt heartwood, a large potential source of thujaplicins is available if profitable uses are found as a result of research.

The thujaplicins are of considerable interest to research workers in biology, botany, biochemistry and medicine because of their fungicidal properties and chemical relationship to colchicine, a tropolone derivative well known in plant genetics and medicine for its effects on cell division.

Samples of the thujaplicins may be prepared by steam-distilling cedar sawdust. However, the occurrence in the volatile oil of at least three other interesting chemicals (7-hydroxy-4-isopropyltropolone, thujic acid, and methyl thujate) complicates the separation procedure. The compound 7-hydroxy-4-isopropyltropolone (IV), which has only recently been discovered in cedar wood (11), is a thujaplicin containing an additional vicinal hydroxyl group which considerably modifies its reactivity and toxicity. It occurs in cedar at only one-tenth the concentration of the thujaplicins, and also has a much lower toxicity to fungi.

A simple and inexpensive method of preparing samples of this substance and the thujaplicins from cedar has been discovered (11). The method is based on their ability as tropolones to react with metallic copper. During kiln-drying of cedar products, a certain amount of steam distillation occurs and, therefore, the atmosphere in the kiln contains very small concentrations of the components of the volatile oil. If copper metal is exposed in the kiln, the tropolones react with it to form a stable chelate which appears as a green coating on the metal. Thus by exposing copper screening in the free spaces of commercial kilns drying cedar, and periodically washing off the green deposit with chloroform or benzene, a solution of the copper chelates of the tropolone fraction of cedar is obtained.

Since other components of the volatile oil such as thujic acid and methyl thujate do not react with copper, collection and purification is achieved in one convenient operation. This collection procedure may of course also be applied to laboratory or plant steam distillations by bringing the vapor into contact with finely divided copper. The tropolones are recovered from the copper derivative by treatment with hydrogen sulfide or strong acid.

The non-tropolone components of the volatile oil, thujic acid and its methyl ester, also have an unusual chemical structure. When first isolated from cedar wood in 1933, the former was believed to be dehydroperillic acid (20), but was finally shown to have an unsaturated seven-membered carbon ring structure (V) in 1949 (9). It is a colorless, odorless, crystalline organic acid which is of low toxicity to fungi. It is unstable, and is readily rearranged to cuminic acid (p-isopropylbenzoic acid). The methyl ester of thujic acid has a fragrant cedar odor and is mainly responsible for the characteristic fragrance of western red cedar (13, 3). Results of preliminary tests at the University of Massachusetts indicate that this compound has some toxicity to larvae of the black carpet beetle, the furniture carpet beetle, and the case-making clothes moth.

The yield of steam-volatile oil from cedar wood varies with the source of the wood and the efficiency of the distillation. In the Vancouver laboratory, yields of 0.3 per cent have been obtained from mill-run sawdust in small-scale distillations. The product was approximately one part thujaplicins, one part thujic acid, and two parts methyl thujate. Selected samples have given yields of up to 1.2 per cent of thujaplicins and up to 0.68 per cent thujic acid.

The Acetone Extractive

When cedar heartwood is treated with acetone, a complex mixture of substances is extracted (3). The product, obtained in yields of 12 to 1[illegible] per cent from butt heartwood, is approximately 90 per cent phenolic, the balance consisting of arabinos (1) an unidentified sterol, and the components of the volatile oil. The phenolic material is a mixture of at least eight individual substances, seven of which can be dissolved in hot water. The insoluble remainder is probably a mixture of Braun's "native" lignin and phenols more highly condensed than those in the water-soluble portion. The concentrations in the wood of the pentose, arabinose, and of the supposed sterol are in the order of 0.[illegible]5 to 0.3 and 0.1 per cent, respectively.

The Hot Water Extractive

If hot water is used as the extracting solvent, the extractive obtained is mainly phenolic. It has the same components as the acetone extractive with the exception that it, of course, lacks the water-insoluble phenolics. The distribution of hot-water solubles and the phenolic portion thereof in the wood follows the same pattern as that found for the thujaplicins. They are remarkably dependent on the position in the tree and on the color (15, 16). In one cross-section from the butt of a mature tree, the hot-water solubility ranged from 1.2 per cent near the pith to 22.8 per cent at 13.5 inches from the pith, a 19-fold increase.

Phenolic Components

The phenolic portion of the water extractive is the same complex mixture of phenols as found in the water-soluble portion of the acetone extractive. It gives color reactions with ferric chloride, ammonium molybdate, and chloropentammine cobaltic chloride (purpureo salt) that are characteristic of pyrocatechol (1, 2-dihydroxybenzene) derivatives. Unlike the tannins, the mixture is not absorbed by hide power and has a high methoxyl content. The methoxyl content is 4.2 per cent, whereas that of true tannins is generally low, in the 0 to 5 per cent range. The content of hydroxyl groups, methylatable with diazomethane (presumably phenolic), is about 1[illegible] per

cent whereas that of tannins ranges from 15 to 25 per cent.

As in the case with other components of the extractive, the cedar phenols have an important effect on the properties of the wood and the way in which it may be utilized. Their toxicity to fungi is of the same order as that of zinc chloride (19), which is roughly one two-hundredth of that of the thujaplicins. However, since the concentration of the phenolic fraction, particularly in the heartwood of young trees is frequently 20 to 100 times that of the thujaplicins (15), it is apparent that this fraction as well as the thujaplicins has an important role as a natural preservative for cedar.

The mixture of phenols, as isolated from cedar wood, has a low fusion point of 125 to 130° C. It is possible that this material acts as a lignin plasticizing agent in place and thus accounts for the remarkable stabilized densification of cedarwood by heat and pressure (4).

Because of their pyrocatechol nature, the phenols in the presence of moisture readily corrode steel with the formation of a blue-black deposit. This action makes it advisable to use coated nails in exposed cedar construction to avoid staining and corrosion problems. The thujaplicins also readily react with steel to form a red substance, the ferric chelate, and, therefore, if steel is left in contact with moist cedar wood, the resulting stain may range from blue-black to red in color.

The pyrocatechol grouping in the phenols also accounts partly for the accelerated corrosion of mild steel digesters, which is encountered during alkaline pulping of western red cedar. These substances in alkaline solution have the ability to dissolve steel even in the presence of sulfide (17). The thujaplicin reaction with steel does not take place in the presence of alkali, hence any attack on pulping digesters by these substances is confined to the vapor spaces during heating and filling operations. Fortunately, the corrosion problem due to the cedar extractives may be avoided by the use of digesters lined with carbon brick, stainless steel, or inconel. Alternately, if profitable uses for the extractives are developed, the chips might be extracted before they are pulped and special linings would then be unnecessary.

Determination of the chemical structure of the cedar phenols has had to await the development of satisfactory methods of separating the individual phenols in pure form from the complex mixture in which they occur. Because of their reactivity and sensitivity to oxidation, great care must be exercised during their isolation. One of the components, roughly 45 per cent of the mixture, may be isolated from the mixture on the basis of its poor solubility in ethyl acetate, which readily dissolves the other phenols. This substance, for which the name plicatic acid is suggested, is a phenolic acid that contains methoxyl groups and unetherified pyrocatechol groupings. It readily decarboxylates when heated to 120° C. with the evolution of carbon dioxide. Preliminary studies on plicatic acid and another main component that has been isolated indicate molecular weights in the 400 to 500 range. Further research on the structure of these substances is in progress.

Possible Applications

An increased knowledge of the chemical structure of the cedar phenols will assist in developing uses for them. Meanwhile, in view of their phenolic nature, their potential usefulness in adhesives, anti-oxidants, drilling muds and dispersing agents should be explored. Their content of pyrocatechol groups suggests investigation of their usefulness in metal cleaning and etching, sequestering agents, and electrolytic refining.

It is evident from the foregoing that the extraneous components of cedar have a varied and interesting chemistry that materially affects the way in which the species can best be utilized. The possibility of industrial production of useful chemical by-products based on these components requires further study. In view of their unusual nature and chemistry, however, and the ease of extraction, the high concentrations occurring in the wood, and the availability of the species, there is good reason for optimism that continued research will result in important developments.

Summary

The extraneous components of western red cedar, which frequently exceed 20 per cent of the wood weight, consist of the volatile components: α, β, and γ thujaplicin, 7-hydroxy-4-isopropyltropolone, thujic acid, and methyl thujate; and the non-volatile components: arabinose, an unidentified sterol, and several uncharacterized phenols.

The tropolone derivatives, the thujaplicins and 7-hydroxy-4-isopropyltropolone, and also the phenols, are natural preservatives and their presence in the heartwood accounts for the high natural decay resistance of the species. The presence of these two groups of compounds also accounts for the digester corrosion encountered in the sulfate pulping of cedar and the staining reactions which the wood is subject to in association with steel.

The concentration of the thujaplicins, the water-soluble phenols, and the total hot-water solubility of the wood undergo wide variations. They depend on the position of the sample in the tree and the color of the wood. Concentrations of up to 1.2 per cent of the thujaplicins and up to 23.3 per cent of the water-soluble phenols have been found.

The tropolones may be conveniently collected by bringing the vapor from the wood being dried in a kiln or from steam distillation of the sawdust into contact with copper metal. The tropolones react with the copper to form a green deposit, which may be collected in chloroform solution and treated with hydrogen sulfide to regenerate the tropolones.

Methyl thujate is mainly responsible for the characteristic smell of cedar, and according to preliminary tests has some toxicity to the larvae of carpet beetles and the case-making clothes moth.

Chemical studies on the properties and uses of the phenolic components, which are derivatives of pyrocatechol and constitute 80 to 90 per cent of the acetone and hot water extractive, are continuing. One of the phenols isolated is acidic and has been named plicatic acid. Pending further studies, some potential uses for these substances based on their phenolic nature are suggested.

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Discussion

F. L. Brown (Dow Chemical Co.): What fungus was involved in the butt-rot portion of the wood shown in the slide?

Mr. Barton: I don't know the identity of the micro-organism. It is commonly referred to as cubical cedar butt rot.

Mr. Brown: Has the chemical study been paralleled by a cytological study?

Mr. Barton: Yes, the amount of decay and concentration of thujaplicin have been correlated. As you would expect, the lower the thujaplicin content the greater was the decay.

W. M. Hearon (Crown-Zellerbach Corp.): Have you named the hydroxy thujaplicin?

Mr. Barton: Yes, we call it 7-hydroxy-4-isopropyltropolone. The complete chemical name is 2, 7-dihydroxy-4-isopropyl-2, 4, 6-cycloheptatrien-1-one.

E. C. Jahn (State University of N. Y. College of Forestry): Have you made any attempt to define the reasons for the distribution of thujaplicin which you observed, particularly in old trees?

Mr. Barton: Not really. We know it's allied to both color of the wood and position relative to the pith. We have no indication of migration of the thujaplicin from one part of the tree to another. Since young trees are usually very low and older ones usually high in thujaplicin, it appears that the tree doesn't start to produce much preservative until it starts to age. The common occurrence of butt rot with sound adjacent heartwood in older trees certainly illustrates this fact that the preservative content of the first wood next to the pith was low. Of course, superimposed upon the pattern of radial increase of natural preservatives is the color pattern.

J. L. Ziegler (Arthur D. Little, Inc): Is the distribution of the preservative a straight line, or as sharp a difference in concentration as the color slide indicates?

Mr. Barton: In young trees the change in concentration throughout the wood is more gradual than in older trees. However, in older trees where there is a distinct color change from dark to very light there will be sharp difference in thujaplicin content. Interestingly enough, internal or included sapwood has no thujaplicin content and hence has no more resistance to decay than normal sapwood.

Mr. Hearon: I wonder if the color is due to an absence of thujaplicin rather than the other way around. That is, perhaps the color is due to fungus action occuring in the absence of thujaplicin?

Mr. Barton: This is possible. However, the picture may be complicated if young, light-colored poles showing 0.3 to 0.4 per cent thujaplicin, become mature trees with dark brown heartwood.

Mr. Hearon: The source of your trees is probably important here. For some young trees on which I've seen tests, some showed only 0.05 per cent.

Anon.: What is the relationship between the extractives of incense cedar and western red cedar?

Mr. Barton: Zavarin and Anderson have reported the presence of B and Y thujaplicin in incense-cedar heartwood.

Variations in Moisture Content of Air-Seasoned Southern Pine Lumber in Georgia[1]

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AND

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Lumber in 20 yards was air-dried by four methods. Conventional flat-piled boards were most uniform in moisture content, while package-piled, end-piled, and crib-piled boards showed increasingly serious variations. Degrade loss was highest in flat piles, however, and lowest in package piles.

DURING THE SUMMER OF 1956, a detailed study was made of the air-seasoning practices and results at 20 Georgia lumber yards. Detailed information was obtained from 21 stacks containing almost 42M board feet of lumber. Individual boards totaling 8,849 board feet were studied in detail for seasoning degrade and moisture content. A report on yard conditions, monetary losses, and average moisture content is in process of publication[2] and is intended for general information of lumber dealers. Information on variation in individual moisture content readings is believed to be of primary interest to technicians and other research workers, and is the material included in this report.

Stacking Methods Studied

The four methods in common use in Georgia for air seasoning pine lumber are flat-piled, package-piled, end-piled, and crib-piled.

"Flat-piled", as used in this study, conforms most nearly to the old method of hand stacking lumber by flat piling in 8-foot or wider piles. Piles constructed in this manner are usually found on hand-operated yards as opposed to mechanized yards. They may or may not be sloped, pitched, or covered, and are usually set on some kind of foundation so that the bottom courses are not in contact with the ground (Fig. 1). Four piles of flat-piled lumber containing 8,998 board-feet were studied.

"Package-piled" lumber is put up in unit packages for convenience of handling. These packages are usually 8 feet or less in width and are often made to conform to the dimensions of kiln trucks on those yards that kiln dry their better or special grades. Most package piles consist of several unit packages separated by members called bolsters. These packages, transported by fork-lift trucks or similar devices, are a necessary part of yard mechanization (Fig. 2). Seven package-piled stacks containing 18,093 board-feet were studied.

"End-piled" lumber refers to lumber stacked on end in a series of parallel courses. An "end pile" might be best described as a flat pile stood on

[1] Presented at Session IX, Wood Drying, at the Eleventh National Meeting of FPRS, June 23-28, 1957, in Buffalo, New York.

[2] An analysis of this study entitled "Value losses from Air-Seasoning Southern Pine Lumber in Georgia", by Page and Carter, has been submitted to the Southeastern Forest Expt. Sta., Asheville, N. C., for publication as a Station Paper.

The Authors: Rufus Page holds a BS in forestry from N. C. State College. Prior to his present position, he did instructing, consulting, and supervisory work in forestry.

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Fig. 1.—In these well-constructed flat piles, lumber dries uniformly and the top courses are protected from both rain and sun by stack cov[illegible].

Fig. 2.—Many yards in Georgia are mechanized by stacking lumber in unit-package piles.

Fig. 3.—There is a distinct moisture gradient in end-piled lumber, with the bottom ends containing the most moisture and the top ends the least.

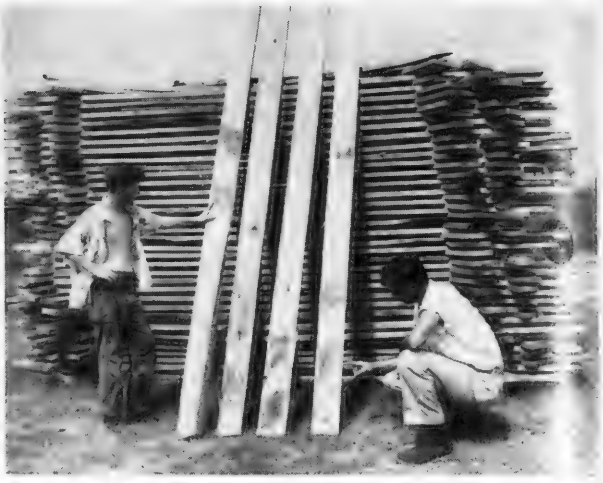

Fig. 4.—Both heavy blue stain and decay often occur in crib piled lumber that has been piled for long periods of time. Boards also bow excessively at the unsupported centers.

end. In many of the larger yards, lumber is end-piled in stacks containing 25M feet or more, since the length of the pile is limited only by the available yard space (Fig. 3). In this study, three end-piled stacks containing 5,880 board feet were examined.

"Crib-piled" lumber is stacked by means of flat piling in a 3-sided pen or crib. A crib whose sides consist of a single tier of boards is "single cribbed," of 2 boards is "double cribbed" (Fig. 4), and of 3 boards is "triple cribbed." Seven crib piles containing 8,593 board-feet were studied.

Moisture Content Determinations

Moisture content determinations were made to find the effect of different methods of stacking on drying times and on the uniformity of lumber moisture content. Moisture content readings made with a resistance-type meter were taken at a point 6 inches from one end and at the center of each sample board in the flat, package, and crib piles. An additional reading was taken from each board in the end piles to provide a top, middle, and bottom reading. A few additional readings were taken where boards lapped in the crib piles.

Effect of Drying Time on Moisture Content

All stacks selected for the study were considered by yard operators to be air dried. Measurement of average moisture content for each pile confirmed this opinion, but when individual board moisture contents were analyzed, it was found that many boards would not pass Southern Pine Inspection Bureau requirements.[3]

The piles studied had been up for periods ranging from 19 to 173 days, but, except for end-piled lumber, the average moisture content showed no relationship to the length of drying time (Table 1). The surprising lack of relationship is possibly due to the extremely good drying weather during the study and the fact that no piles that dried for less than 19 days were studied. A supplemental study is now under way to ascertain moisture contents in each type of pile from the day the pile is set up.

One might expect to find the highest number of moisture content readings above 19 per cent in the piles that had been drying the shortest time but this does not hold true except in the cases of end piles (Table 2).

Based on the data in Table 2, it becomes apparent that factors other than the length of drying time must account for the individual moisture content variations observed in this study.

Effect of Method of Piling On Uniformity

There was considerable lack of uniformity in moisture content of the piles studied, even though the pile averages showed less than 20 per cent moisture content and tended to indicate uniformity. In all, 2,911 moisture content readings were taken on 1,347 separate boards, with 15.3 per cent above 19 per cent moisture content (Table 3).

It is obvious that the conventional flat piles provided the greatest uniformity in moisture content, with no other method showing good results.

[3] Moisture content requirements for Southern Pine Inspection Bureau graded southern pine 4/4 lumber state that any board containing more than 19 percent moisture content shall be rejected as below grade.

Table 1.—AVERAGE MOISTURE CONTENT OF PILES BY METHOD OF PILING AND DAYS OF DRYING

Method of piling	Days of drying																
	19	20	21	31	33	35	36	42	48	51	70	76	92	104	123	137	72
	Average Moisture Content, per cent																
Flat	----	----	----	----	12.2	----	----	----	----	----	----	12.2	----	----	14.4	13.4	
Package	----	----	----	17.5	14.9	----	----	17.6	11.9	17.3	----	----	17.6	11.0	----		
End	19.2	----	16.9	----	----	----	15.8	----	----	----	----	----	----	----	----		
Crib	----	13.8	----	----	----	14.7	----	----	----	----	13.2	----	----	----	----		14

Table 2.—PER CENT OF INDIVIDUAL MOISTURE CONTENT READINGS ABOVE SPIB SPECIFICATIONS[1] BY LENGTH OF DRYING TIME

Method of piling	Days of drying																
	19	20	21	31	33	35	36	42	48	51	70	76	92	104	123	137	2
	Per cent of Readings Above SPIB Specifications																
Flat	----	----	----	----	0	----	----	----	----	----	----	0	----	----	4.9	8	
Package	----	----	----	40.0	8.1	----	----	25.4	0	15.6	----	----	21.8	0	----	----	
End	33.0	----	17.5	----	----	----	5.8	----	----	----	----	----	----	----	----	----	
Crib	----	4.1	----	----	----	5.1	----	----	----	----	10.6	----	----	----	----	----	2

[1] Specification of 19 per cent moisture content.

Another way to illustrate the expectancy of acceptable moisture content by different piling methods is a cumulative frequency probability (Table 4). Based on the lumber studied, it can be expected that 98 per cent of the flat-piled lumber will be within moisture content specifications, while 87 per cent of the package-piled lumber, 95 per cent of the crib piled, and only 82 per cent of the end-piled lumber will be within specifications.

Although the data look fairly good for crib-piled lumber, it should be pointed out that most measurements were made between the laps. Toward the end of the study, moisture content readings were taken at the laps, and 28 out of 29 were well above 20 per cent. In fact, the average moisture content under the laps was 33.6 per cent. If moisture content readings had been taken at laps of all boards studied, it is believed that the majority of the crib-piled lumber would not meet content specifications.

One of the most significant results of this study lies in the fact that the moisture content at lap joints in crib-piled lumber seems to increase with the length of seasoning, as shown in the following tabulation.

Length of seasoning (Days)	Average moisture content at laps (Per cent)
20	22.2
35	31.8
70	39.9

The reason for this increase in moisture content at the laps has not been determined, but it is suspected that mold and decay fungi at these points increase the porosity of the wood, thereby increasing water absorption from rain and condensation. This porosity is well known in the wood-treating industry, where fungi-infected posts or lumber absorb greater amounts of treating chemicals than does uninfected wood.

Effect of Position in Pile on Moisture Content

In all methods of piling, there was a gradient from low moisture content at the tops of the piles to a higher moisture content at the bottoms, ranging from 12 to 15 per cent in crib piles to 16 to 19 per cent in end piles (Table 5).

Although it might be expected that the variability would be the greatest at the bottom of the piles, where the moisture content is highest, such is not the case. In fact, coefficients of variation ranged from 20 to 35 per cent at the tops of the piles, from 11 to 23 per cent in the middle sections, and from 9 to 24 in the bottom sections.

Again, the moisture content variations shown for crib piles are misleading because the moisture readings at laps were not classified by position in pile and are not included in Table 5. The variations shown are for board areas between laps.

End piles show the greatest average variation but package piles show the greatest coefficient of variation.

Table 3.—NUMBER AND PER CENT OF BOARDS ABOVE 19 PER CENT MOISTURE CONTENT

Method of piling	Boards measured No.	Boards above 19 per cent No.	Boards above 19 per cent Per cent
Flat	306	9	2.9
Package	628	125	19.9
Crib	299	30	10.0
End	114	42	36.8
Total	1347	206	15.3

Conclusions

The four common methods of piling southern pine lumber for air seasoning usually result in average moisture content below 20 per cent after 3 weeks or more of good weather. The uniformity of moisture content is generally poor, however, with over 15 per cent of individual boards having more than 19 per cent moisture at some point. This situation is most serious in crib-piled lumber, since the laps apparently do not dry to specifications, and even gain moisture the longer the pile is left standing.

End-piled lumber dries rapidly but has a moisture gradient from the top to the bottom of the vertically stacked boards; moisture content is often excessive in the lower portion.

Contrary to expectation, the conventional flat-piled lumber showed the greatest uniformity. Package units, with shorter air travel through the piles, showed surprising lack of uniformity. The reason for these differences is not apparent without further study.

Although uniformity of moisture content shows up best in flat piles, degrade losses are highest here, and lowest in package piles, the difference being about $15 per M board feet.

The general trend to mechanization and package piles seems to be a good move for the lumber industry from the standpoint of reduced labor and less degrade loss. Variation in moisture content in package piles may be the result of careless methods brought about by the use of new equipment. This variation should be subject to control when further studies reveal its cause.

It should be pointed out that this paper reports only on one phase of a larger study involving degrade losses from methods of piling.

Discussion

D. L. Davies (Koppers Co. Inc): With reference to the increase in moisture content of lumber, did blue stain increase with time? Was most of the lumber dip treated?

Mr. Page: Both the intensity of blue stain and the moisture content increased with time. We do not know how much of the lumber studied was dipped for stain control.

R. L. Youngs (U. S. Forest Products Laboratory): In making moisture content determinations, was any attempt made to evaluate the type of moisture gradient across the thickness of the boards?

Mr. Page: Moisture gradients were not recorded, although a gradient was noticed from the surface to the core following rains or on boards exposed to the sun.

R. H. Elliott (Standard Dry Kiln Co.): Was a study made on moisture content variation according to height of package piling?

Mr. Page: Each package was treated

Table 5.—MOISTURE CONTENT VARIATIONS BY METHOD OF PILING AND POSITION OF PILE

Method of piling	Top MC[1]	Top SD[2]	Top CV[3]	Middle MC[1]	Middle SD[2]	Middle CV[3]	Bottom MC[1]	Bottom SD[2]	Bottom CV[3]
Flat	11.83	2.36	19.94	13.59	1.45	10.66	16.20	1.50	9.25
Package	14.29	5.03	35.19	15.81	3.75	23.72	16.56	2.82	17.03
End	15.69	4.04	25.75	17.02	3.02	17.70	19.36	4.66	24.07
Crib	11.72	2.76	23.55	13.82	2.11	15.34	14.63	1.40	9.56

[1]Average moisture content.
[2]Standard deviation.
[3]Coefficient of variation.

Table 4.—CUMULATIVE FREQUENCY PROBABILITY OF MOISTURE CONTENT 19 PER CENT AND ABOVE

Method of piling	Moisture content of boards, per cent: 19	20	21	22	23	24	25	26	27	28	29	30 plus
	Cumulative Frequency Probability in Per cent											
Flat	98.2	99.6	99.8	99.9	99.9	99.9	99.9	100.0				
Package	86.6	91.6	93.6	95.4	96.7	97.2	97.6	98.0	98.3	98.9	99.1	99.7
Crib	95.1	95.1	95.8	96.2	96.6	97.0	97.2	97.7	97.9	98.1	98.3	98.5
End	81.8	87.1	90.9	93.2	95.0	95.9	96.5	96.5	97.1	97.4	97.7	98.0

as a unit, but no correlations were made based on elevation of different packages.

N. C. Higgins (Michigan State University): What was the area distribution of the different types of piling?

Mr. Page: Some yards contained all four methods of piling, but many yards practiced only two.

S. B. Preston (University of Michigan): Was the moisture gradient from top to bottom rather uniform in end piling?

Mr. Page: Yes, it was.

Anon.: Have you looked into the possibility of covering lumber piles with materials that will increase solar heat?

Mr. Page: We have not seen such practices used in Georgia, nor have we tried them experimentally.

Evolution of a Quality Control System for Particle Board[1]

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The evolution of the quality control program at U. S. Plywood's Novoply operation is described. Simply stated, the objective of the program is only to reduce the variation in the finished product to the greatest practical economic extent.

WHEN THE NOVOPLY PLANT at Anderson, California, went into production in 1951, quality control was set up on the basis of issuing instructions to the foremen and operators to maintain certain operating conditions throughout the plant. It was hoped that 100 per cent acceptable production would be made that could be trimmed, sanded, and loaded into the box cars. One young laboratory technician was employed and provided with facilities for testing modulus of rupture in bending, a balance and micrometer for measuring density, and a water bath, clock, and micrometer for measuring swelling. Management planned to sample the production every few hours and run these few control tests as a watchdog on the operation. The MOR testing machine was a shot-loaded beam device and required weighing the shot to determine what force had been applied in breaking.

It did not take long to discover, however, that the market being served was more critical in its expectations of quality. The customers soon began to tell what they expected of the product, and the few simple tests were not at all adequate to assure that daily production was meeting these expectations. Since U. S. Plywood was the first one in this type of business in the United States, the dilemma immediately arose that there were no established tests for measuring some of the properties that we had to measure.

Step 2

Step No. 2 in the evolution of quality control was a development program to devise practical tests for measuring such things as resistance to delamination in the face, screw-holding power, and resistance to splitting in the core. Resistance to splitting in the core became important because many customers were routing the edge and driving in T moldings, which frequently apply a considerable wedging force. But in addition, the customers quickly found this particular test was an indication of the general physical status of a molded particle board panel. Face delamination is primarily important because the customers machine the panel subsequent to overlaying with plastic laminates. Very frequently, the machining creates a tearing action and, if the face is not tenaciously adhered, it will break the panel at this point.

Out of this development program came the face test, tensile shear test, and screw-holding power test now employed. The additional testing required put quite a burden on the laboratory, and for a while three testers were spread over three shifts a day in order to keep up. This, of course, led to further development and modification of the tests to the point where they were more commercially practical for production control purposes, and led to the purchase of a universal testing machine and other quality laboratory equipment. Ultimately, even though the frequency of sampling was increased, the testing routine was so improved as to permit returning again to one shift for one technician.

Step 3

The next step, however, increased the staff to six, including the tester, in order to analyze test results and translate this back into adjustment of process variables. This period served its purpose in that it gave a full understanding of the effects of process variables. Thereafter, it became apparent that this was retrospective effort being devoted to determine whether the horse was out of the barn.

Step 4

As a last step in the evolution, Shewart Control Charts were put into use to record test results. The major part of the quality control effort was then shifted into the plant to control the panels as they were being made, and regular testing and control charts were relied upon as watchdogs for the finished product.

Quality Control Program as it Exists Today

Early in 1956, after approximately five years of evolution, the following quality control program was put into effect.[2] Quality control at the Novoply Plant now consists of three phases:

I The Man on the Job: This is one of the most vital links in any manufactured product, as everyone realizes that the best place to avoid a defect is not to make it in the first place. The most difficult and the most important point to remember in regard to the man on the job is that this man must have a desire to produce good quality. This is basically a human relations problem, which is best solved by a combination of the following factors:

A. For obvious reasons, every effort should be made to obtain and keep men with the greatest capacity and ability that are available.

[1] Presented at the Northern California Section Meeting, FPRS, held May 2–3, Berkeley, Calif.

[2] See paper presented by R. M. Bailey, Regional Conference on Quality Control on March 18, 1955, published in American Society for Quality Control—Proceedings of 2nd Western Regional and Pacific Northwest Quality Control Conference, Seattle, March 18–19, 1955—Contechnical paper No. 4.

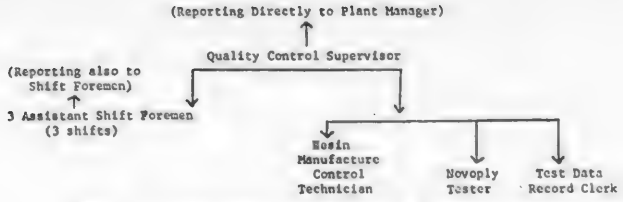
(Reporting Directly to Plant Manager)
Quality Control Supervisor
(Reporting also to Shift Foremen)
3 Assistant Shift Foremen (3 shifts)
Resin Manufacture Control Technician
Novoply Tester
Test Data Record Clerk

Fig. 1.—Organization of the Quality Control staff.

. Quality control must be preached and sold at all times by the supervisors. In many cases, a pretty good selling job has to be done to these supervisors to have them wholeheartedly impressed with the importance of quality. The supervisors must talk individually with their men as often as possible with regard to the importance of quality. Since every man basically has a desire to be well thought of, these talks primarily are aimed at combating a lack of awareness, which is more often than not the greatest enemy of quality control.

C. Quality control must also try to capitalize on people's love of competition. Each week, charts are posted that indicate to each shift how they stand in relation to the other shifts. Foremen are very conscious of these charts, and the men also take great interest in them. There is little doubt that this adds a great deal to the quality control picture.

D. As an aid to selling quality control, posters around the plant and in the lunchroom periodically display very cleverly the importance of quality and team effort in the survival and well being of any company. While it is difficult to assess the value of these, management feels that it does add to the over-all team effort.

The particle board industry is certainly quite automation-minded, and is becoming more so quite rapidly. Automation serves a dual purpose in that, beside reducing unit costs, it allows a great portion of the operators to become 100 per cent quality control men. At several of the important stations in the plant, the men do nothing except check various flow rates, moisture contents, and so forth, which places them as 100 per cent quality control operators. This has served as a very great contribution towards being able to reduce substantially the variation in the final product.

II Testing and Supervision on the Job: Because of a fundamental belief in the importance of quality control, the assistant foremen have been assigned the responsibility for the quality of the product on their respective shifts. This is contrary to most thinking in regard to plant organization in that these men take direction from the Quality Control Supervisor and Plant Manager as well as from the shift foremen for whom they work. These assistant foremen are carefully chosen for their jobs. The present group were the men previously employed in the earlier quality control group whose job was to analyze test results. Any replacements will be trained first in the testing laboratory. In spite of careful selection and previous training of these assistant foremen, there is a rather elaborate educational program going all of the time, which is supervised and directed by the Quality Control Supervisor.

It is difficult to get a genuine appreciation of the fact that quality control is nothing more than reducing the variation in the finished product to the greatest practical economic extent. Behind these variations lies the whole relatively untapped field of statistical applications, which must be intelligently applied in order to distinguish when variations are assignable or whether they are a result of chance. To provide a basic understanding of the application of statistical methods, an assistant foremen's handbook has been written which these men learn. Each month they are given written tests and graded to make sure that they know their jobs. This seems to be the best and only way to tell clearly how the educational program is functioning. This test is given after a brainstorming bull session where basic future objectives are brought out.

The assistant foreman has his office situated directly in the heart of the plant, and daily takes direct measurements on many variables at various stages of manufacture. He also supervises the operators from a quality standpoint. The data that he gathers are immediately plotted on statistical quality control charts so that, when and if any of the variables depart from the process average, the Shewart Control Charts tell him whether it is a result of chance or whether an assignable cause for variation exists.

It is difficult to overestimate the value of isolating the cases where there is an assignable cause for variation and taking remedial action during the process. Individual Shewart Control Charts are kept on each of the process variables. These charts are kept up to date, and the assistant foremen have a log book by which they pass along to the next shift any explanation of difficulty or any other information that might be helpful to an oncoming shift.

The Quality Control Supervisor daily inspects and analyzes these charts and each month writes a Quality Control Report, which tabulates the average values, the average ranges, and the various control limits, so that a permanent record for ready reference is available at all times.

III Finished Product Testing: Management feels that it is essential to test the finished product routinely. For this reason, every hour and a half a sample is cut from a freshly made panel in a completely random manner. These samples are tested for 1) tensile shear strength, 2) density, 3) screw-holding power, 4) face strength, 5) swelling, and 6) residual moisture content. As previously explained, tests were developed to suit the manufacturing operation, and the various routine tests mentioned above do not coincide with ASTM standards. While the ASTM tests are excellent, the tests used are more nearly suited to the product. For example, the modulus of rupture is a very fine test and is very important to the final consumer; however, since our particle board is a three-ply construction, the component plys are tested separately so that the trouble can be diagnosed more quickly in the plant. The modulus of rupture test is very sensitive to the outer plys, but it is also influenced by the main body of the board to a degree. Then too, the modulus of rupture of our board is sufficiently high to be non-critical for most customers.

It should be pointed out that while we use terms such as modulus of rupture, tensile shear, screw-holding power, and so forth, we are faced with a unique situation insofar as we are testing a sandwich construction. This concept does not normally allow simple mathematical interpretations that follow the old Newtonian law of mechanics, but does require careful and precise interpretation.

Tensile Shear Strength: The tensile shear test is made by kerfing a 2 by 6 inch sample to the center on opposite sides of the specimen to present a simple shear plane of 2 inches by ½ inch. This specimen is pulled apart in a direction in the simple shear plane. This particular test for center ply is not influenced by the physical properties of the face plys. The ASTM tensile perpendicular test would test the same feature of the board, but our test is simpler to use and very reliable. A Dillon Universal Testing Machine is employed.

Density: The density is checked on the shear specimens before they are kerfed, and it is important to test the density of each shear sample because of its powerful influencing effect on shear strength. In addition to the density checks on these small samples, the assistant foremen keep control charts on the gross panel weights, and also various shipments are spot checked for density just prior to carloading.

Screw Holding Power: Screw-holding power is determined with an 8 by 5/8 inch sheet metal screw. The Dillon tester is used. Normally, this test is conducted just to maintain basic process averages rather than to indicate trouble in the plant. The screw-holding test itself is not felt to be a particularly good quality control test because it is influenced by the ability of the tester to put the screws in perfectly straight and turn them to a uniform depth. Here again, screw-holding power is very sensitive to board density and all test values must be interpreted in relation to the given density. For this reason, the screw-holding power is actually taken on the same sample as the tensile shear test, after the shear test has been taken.

Face Strength: While the shear test is the basic tool to determine the core properties, a face test is used to measure the strength of the faces. This again is a test that has been arbitrarily developed to suit specific needs, and would not be particularly beneficial to one-ply particle boards. Since we are dealing with a sandwich construction, it is not only important that the faces have high strength within the face itself, but also that they be integrally bonded to the core. A circular steel tab of one inch area is bonded to the surface of the board, and is pulled off in a direction perpendicular to the board. The board sample is large to prevent a tensile failure in the core. The resulting wood failure in the surface is numerically recorded then as pounds per square inch of face strength. The Dillon tester is used. It may be of interest to note that every once in a while these tabs have a glue failure and do not pull wood. In such cases, the value is automatically discarded and a new value is determined.

Swelling: The water resistance of any wood product is of paramount importance, and the swelling of the board is routinely checked. Most of the conventional tests are 24-hour total immersion determinations, and this is much too long a time for management to wait for this information. A swellometer was developed, which is merely a spring-loaded device that automatically measures the per cent swelling without the usual time-consuming micrometer determinations. Into this swellometer are inserted 5 coupons at a time, each of which is a 1 1/16 inch diameter round plug cut by means of a hole cutter in a drill press. The swelling samples are immersed for 30 minutes in 100° F. water to accelerate the swellings. This works out very well because the 24-hour total immersion value can be predicted quite closely from the brief swellometer value. The average swelling of the 5 coupons is read directly in per cent from the scale and pointer of the swellometer.

Residual Moisture Content: Each sample is tested for residual moisture content because this oftentimes gives a valuable indication for any abnormal properties and also it is quite important that the board is not too far from equilibrium moisture so that it will stay flat. The procedure here is to use the same type of round plug coupons, slice them in half parallel to the flat faces, weigh them, dry for 1 hour in an oven at 150° C., and reweigh.

In addition to the above laboratory tests, the following tests are carried out at regular intervals in the panel finishing department:

Check on Finished Panel Weights.

Panel Thickness Uniformity and Absolute Thickness Before and After Sanding.

Core and Face Appearance: Every panel is inspected.

Surface Smoothness: This test is accomplished by having the panels, as they come out of the sander, pass under the pickup head of an electronic Brush Surfindicator. The reading obtained on the instrument by means of the diamond stylus is a measurement of surface smoothness.

Shewart Control Charts are kept on all of these post mortem tests for the same reason that they are kept during production—so that management is aware of variations large enough to indicate that an assignable cause for the variation exists. For each of the tests above, four sub-samples are taken so that each hour and a half four shear tests are taken, four densities, and so forth.

Aging Tests: Periodically, a panel is set aside, dated, and stored for testing at one month intervals over a period of five years. Thus, with this overlapping series of panels, a continual knowledge of any effects that age may have on the quality of the product is developed.

The Quality Control Supervisor is responsible for running the testing department, for directing the action of the assistant foremen, and for being sure that all operating instructions are properly posted and kept up to date. The Quality Control Supervisor reports directly to the Plant Manager, and the Production Superintendent has no authority over this man.

Not to be overlooked is the control maintained by manufacturing our own resin binder, which has such a very important influence on product quality.

Summary

And so, from the initial single testing technician and perhaps $500 worth of testing equipment, the staff has grown. Nearly every plant operator carries a considerable amount of quality control responsibility and is taught to understand it. The staff whose specific and exclusive responsibility is quality control is shown in Fig. 1.

Thus, including resin manufacture, a staff of seven are employed solely to safeguard quality, and they have at their disposal many thousand dollars worth of fine equipment.

Cemented Tungsten Carbides and Their Application to the Woodworking Field[1]

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What cemented tungsten carbides are and how their inherent properties have successfully overcome application problems are the dual purposes of this paper. Tool developments and applications are discussed. Procedures for installation grinding and maintenance are described, along with successful methods of jointing. Knife breakage and how it has been overcome are reviewed.

CEMENTED TUNGSTEN CARBIDE TOOLING has been used by the woodworking field for over 25 years. Most of the progress in development, however, has taken place since the war chiefly through the efforts of woodworking tool and equipment manufacturers. It is only in recent years that carbide producers have put forth a concerted effort to develop carbide tooling for this market.

The Carboloy Department (now Metallurgical Products Department) of General Electric Company in 1950 initiated a formal program to investigate and develop carbide tooling, application by application, in various woodworking industries within this field. Progress made to date has resulted in improved tooling on a number of production woodworking operations. At the same time, these activities emphasized the importance of industry education as to what cemented tungsten carbides are, and how they can best be applied to the woodworking field.

This paper has a two-fold purpose. First, to give a better understanding of what cemented tungsten carbides are, and second, to show how their inherent properties have worked in successfully overcoming application problems and promoted efficiency on production machining operations in the woodworking field.

Cemented tungsten carbide is an "easy-to-understand" man-made metal, manufactured through the science of powder metallurgy. It is made by mixing, pressing, and heating powdered metals in varying combinations.

Tungsten carbide, as we know it, does not exist as bar stock, billet, or ingot. Quite the contrary, tungsten carbide is a powder made by mixing powdered tungsten metal and carbon (lampblack) then heating in a furnace at approximately 2730° Fahrenheit (Fig. 1). This actually carburizes the tungsten particles and forms tungsten carbide powder. This powder is stored by various particle sizes that range from 2 to 8 microns.

Tungsten carbide particles cannot be used as a tool in the powder form. They must be bonded together with a suitable binder, usually cobalt metal. This is accomplished by mixing, pressing to shape, and heating the mixed powders in a furnace at approximately 2730° Fahrenheit (Fig. 2). This causes the cobalt to melt and form a matrix which, upon cooling, holds the hard tungsten carbide particles firmly together as a usable tool. Tempering is not required as is the usual case with steel tools. This final heating (sintering) process does not affect the hardness of the tungsten carbide particles, but serves only to bond them together into a usable tool.

All tungsten carbide powder is of the same hardness. Yet, in actual application there are many different grades, each with different hardness, strength, and wear properties. The percentage of cobalt binder and the size of the tungsten carbide particles used will determine the resulting grade of cemented tungsten carbide (as generally applied to woodworking tools). Some grades will actually outwear others by 20 times.

Carboloy grade 883, for example, is composed of 94 per cent tungsten carbide and 6 per cent cobalt binder (Fig. 3). This results in an extremely wear-resistant grade used by the woodworking field on finishing operations. This grade is commonly used on carbide-tipped saws, router bits, and in solid carbide knives. It often outwears steel tools by 50 to 1.

Grade 55A, on the other hand, is a tough, shock-resistant grade that con-

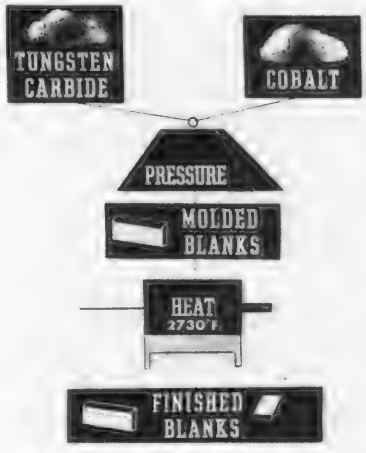

Fig. 2.—*Cemented* tungsten carbide is made by mixing, pressing, and heating tungsten carbide and cobalt powders. This binds the particles together to make a usable tool.

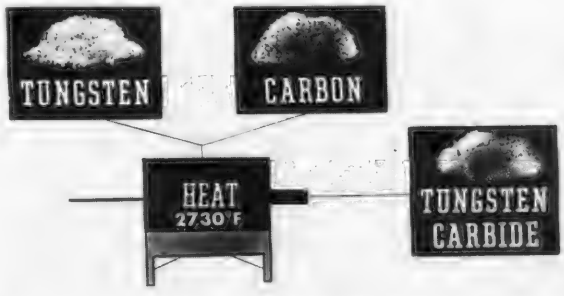

Fig. 1.—Tungsten carbide powder almost as hard as diamond is made by "carburizing" powdered tungsten with carbon (lampblack) at approximately 2730° F.

[1] Presented at Session II, Wood Machining, of the Eleventh Annual Meeting of FPRS, held June 23–28 in Buffalo, N. Y.

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tains 87 per cent tungsten carbide and 13 per cent cobalt (Fig. 4). It is used broadly in the stone-cutting and coal-mining industries and is proving very successful on rough surfacing operations in the woodworking field. Tool life of this grade of solid carbide knives on roughing operations is 20 to 25 times that of present high-speed steel knives.

There are many techniques, processes, and procedures used by the carbide industry to make cemented tungsten carbides. However, knowing the basic principles of manufacture will give a better understanding of cemented tungsten carbide as applied to machining of wood and other nonmetallic materials.

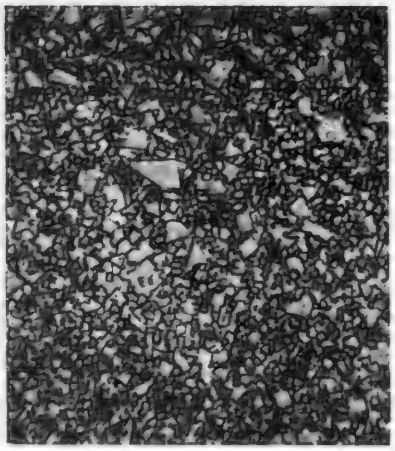

Fig. 3.—Photomicrograph of a wear-resistant carbide taken at 1500 magnification. Note the fine particles of tungsten carbide. The low cobalt content makes it hard to see the bonding agent in this picture.

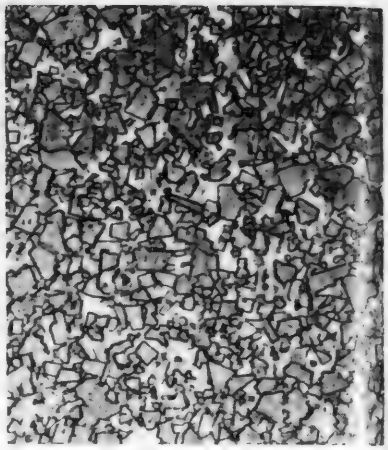

Fig. 4.—Photomicrograph of a tough, shock-resistant carbide taken at 1500 magnification. Note the larger tungsten carbide particles and the light gray areas of cobalt binder.

Properties of Cemented Tungsten Carbide as Applied to Woodworking

The manufacture of cemented tungsten carbide results in a product with properties especially well suited to use as a woodworking tool (Table 1).

Hardness: Hardness, of course, gives wear resistance. When compared to steel, the softest (toughest) grades of cemented tungsten carbide are as hard as the hardest steels. In actual operation, it has been found that, properly applied, the tough grades of carbide will stand greater abuse than will steel knives.

High-Temperature Hardness: Red hardness is a term generally used in conjunction with metal cutting tools. It shows the ability of cemented carbides to hold a cutting edge at red heat. However, this property is most important to the use of cemented tungsten carbide in woodworking. It means that a cemented carbide tool can be elevated to red heat, then cooled, and will return to its original hardness. There is no temper to lose through heat caused by cutting friction or in grinding. Cemented tungsten carbides are not heat treated as are steel tools, and contain no heat treat stresses.

Extreme Density: Cemented carbides are approximately twice as dense as steel. This property acts as a vibration dampener when carbides are used as woodworking tools. The end result is a reduction in the noise factor. This has not been measured by instrument, but has been pointed out by an even more critical test—the operators themselves.

Thermal Conductivity: Thermal conductivity of cemented carbides used for woodworking tools is approximately 4 times that of steel. This means that the heat of friction produced in cutting wood is dissipated 4 times faster in carbide than in steel tools, and the tendency for burn marks on stock being machined is reduced.

Transverse Rupture Strength: These values are established by laboratory tests to determine the strength of various grades of cemented carbides under static load. The smaller figure, for carbides, (Table 1) represents the hardest, most wear-resistant grade, while the larger figure the tougher, more shock resistant. The tougher grades of carbide are in the strength range of the average steel tools used in the woodworking field.

Transverse rupture alone does not determine how a certain grade of carbide will perform on a woodworking operation. Actually, all the inherent properties of cemented tungsten carbide plus proper design and application techniques each play their part in successful performance. Property values act only as guides to the tool engineer when he designs and applies carbide tooling to a specific application.

Ultimate Compressive Strength: The minimum compressive strength for cemented carbide approaches the maximum value for steel (Table 1).

Young's Modulus of Elasticity: Cemented carbides are approximately three times as rigid as steel. In the metal-cutting field, this property is utilized in solid carbide boring bars for boring deep holes. The rigidity of the bar reduced vibration, and thereby improved the quality of the cut. In like manner, solid carbide knives tend to reduce whip in cutter heads operating at 3,600, 5,400, and 7,200 rpm.

These physical properties have made possible the application of cemented carbides to many operations in the woodworking field. In the course of this development work, a number of major application problems have been overcome. These are:

Jointing of Carbide Knives

One of the major problems in the machining of wood is to obtain the proper surface finish (measured by

Table 1.—PROPERTIES OF CEMENTED CARBIDES

Property	Carbide range	18-4-1 High-speed steel heat treated
Hardness	85–93 RA	84 RA (64 RC)
High-temperature hardness	Room temp. 93 RA 1000° F. 88 RA 1200° F. 85 RA	84 RA 77 RA 70 RA
Density	13.0 to 15.2 gms/cm³	8.6 gms/cm³
Thermal conductivity (@ 100° C.	0.17 to 0.29 Cal Cm / Sec °C Cm²	0.062 Cal Cm / Sec °C Cm²
Transverse rupture	175,000 to 365,000 psi	
Ultimate compressive strength	445,000 to 705,000 psi	536,000 psi
Youngs modulus of elasticity (Stiffness)	70 to 105 x 10⁶ psi	30 x 10⁶ psi

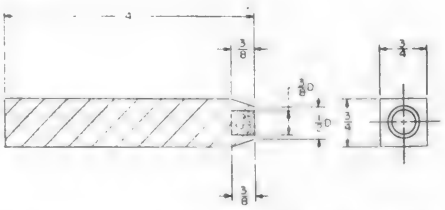

Fig. 5.—Specifications on diamond stone used for jointing carbide knives. Small diamond nib is D180–N100–V3/8. The shank is soft aluminum and is eaten away by the knives as the stone wears.

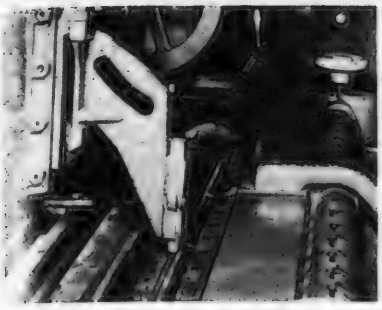

Fig. 6.—Diamond stone set up for jointing knives on a Buss 40-inch single surfacer. Machine surfaces chipboard, glued-up core stock, and rough lumber.

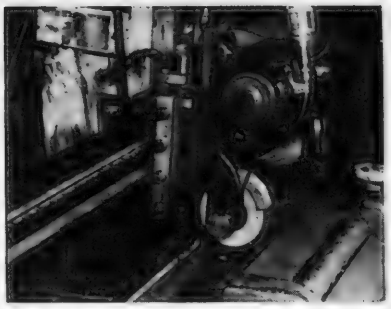

Fig. 7.—Diamond wheel set up on standard grinding equipment of Buss 40-inch planer. Note the drip-cup arrangement for coolant. A felt wick carries just enough coolant (kerosene or similar) to keep the face of the wheel moist. This improves grind and gives greater wheel life.

number of knife marks per inch) on the workpiece. In the majority of finishing operations, this is obtained either by 1) varying machine feeds and spindle speeds or, 2) by "jointing" the knives *in* the cutterhead *while* the machine is running.

"Jointing" is similar to the circle grinding except that the cutter is rotated at normal operating speeds (3600 rpm) against a stationary hone (jointing stone). This grinds ("joints") the edge of each knife so that all knives are operating in the same cutting circle.

Carbide knives were jointed successfully ten years ago. The practice has only become common in the last five years, however. A relatively simple technique has been developed through the cooperative efforts of Buss Machine Works, the Carborundum Company, and Metallurgical Products Department. This jointing procedure has proven very successful in the furniture, flooring, cooperage, and dimension industries.

The jointer stone that is proving most successful is a diamond-impregnated nib mounted in a soft aluminum shank (Fig. 5). This stone is being used with the standard equipment on planers, molders, edge jointers, and flooring side matchers (Fig. 6). Its specifications are D180-N100-V3/8.

Cemented tungsten carbide knives are "jointed" by the same procedure used with steel knives. The following precautionary steps will insure good results, however:

1. Set the carbide knives in the cutterhead to within ± .001 concentricity. This can be done with existing knife-setting equipment *only* if there are no loose bearings and the rolls on the roll-in bar are close fitting and smooth surfaced. A dial indicator may also be used, or the knives can be ground in the cutterhead to bring them into concentricity. The latter method is the best.

2. Be sure the jointing bracket fits snugly on the jointer bar of the machine. Vibration of the stone on the knives will result in fracture of the jointing stone and/or chipping of the carbide knives.

3. Do not "joint" more than .0005 inch of carbide per pass. Carbide knives, *unlike* steel, spark very little (dull red) if any. Contact with the knives is determined by sound. Before the cutterhead is started the stone is brought into contact with the ends of each knife to insure 1) that the jointer bar is parallel, 2) each knife is approximately concentric, and 3) that the jointer stone will not be accidentally fed in too deeply on the first pass.

4. The "joint land", also called heel, on each knife should be only a faint hair line (.003 to .010 inch) on all knives after initial jointing is completed. This can be accomplished without difficulty by careful setting or grinding of the knives in the cutterhead. A light joint gives the best tool life performance, and allows several jointings between grinds.

5. Joint the knives with the cutterhead rotating at 3600 rpm. Since "jointing" actually strengthens the cutting edges of the knives, it is recommended for finishing operations.

6. Should the jointing stone become glazed or loaded, it can be cleaned with a file or hone.

Grinding Carbide Knives

The grinding of solid carbide knives on standard woodworking planers, molders, and jointers is becoming quite common in the industry. In most cases, standard grinding equipment is used to grind the knives in the cutterheads on the machines (Fig. 7).

A diamond grinding wheel is required to grind carbide knives in place of the aluminum oxide wheel used to grind steel knives. Size of the diamond wheel will depend on equipment being used. On planers, a standard periphery-type wheel measuring 4 inches in diameter by 1/4 inch wide does a satisfactory job.

Grinding procedures for carbide are similar to those used on steel knives. Precautionary steps must be taken to insure satisfactory results, however. The following outline has given the best results.

Outline of Grinding Procedure:

1. Check grinding *rail* for rigidity and parallelism with cutterhead.

2. Tighten the sliding unit on the rail. You should *not* be able to "jiggle" the unit after it is tightened. This will make it somewhat harder to feed the unit across the rail, but it is necessary to prevent vibration.

3. Clean and oil the grinding rail for smooth and easy operation.

4. Replace the aluminum oxide wheel on the grinding unit with a diamond wheel. The suggested specifications are. D180–N100–B–1/16. This wheel should be similar in dimension to the wheel now being used, except wheel width can be reduced to 1/4 inch. Operational speed should be approximately 5000 sfpm and a kerosene coolant cup with felt wick should be used. Present speed of unit will probably be alright, but should be checked.

5. Mount the grinding unit on the grinding rail in the usual manner. It fits into a bracket on the sliding unit and is clamped into position.

6. Install the knife stop against which each knife will rest as it is being ground. Be sure that the stop rests against the *face* of the knife, *not* on the clamping gib.

7. Check the setting of the knife stop by measuring the sharpness angle of the *steel* knives. The carbide knives should have a sharpness of approximately 55°. Adjust the knife stop to give at least this angle (to the operator this will mean shortening or lengthening the bevel on the knife). Since there is no way of setting the stop exactly, it must be adjusted by guess according to the sharpness of the steel knives. In many cases, the existing setting will be satisfactory if a face bevel can be incorporated on the carbide knives without a detrimental effect on the cutting action.

8. Set the low knife against the knife stop and release the spring-loaded plunger against the knife setting collar. Some maintenance personnel attempt to use the knife setting collar *only* to position the knives for grinding. *This cannot be done with carbide knives* and will result in inaccurate grinding of knives. *A knife stop must be used to grind carbide planer knives.*

9. Carefully run the grinding unit the full length of the knife. There is

a safety stop at each end to prevent running the wheel into the machine frame. Be sure they are functioning and are in the proper position (diamond wheels are expensive).

10. Start the grinding unit motor and feed the wheel down until it just touches the high point on the low knife. Traverse the full length of the knife carefully in case the grinding rail is not parallel to the knife edge.

11. Feed grinding wheel down .0005 to .00075 inch per pass and grind full length of low knife (one pass considered length of knife and return). Mark down feed dial, back off wheel, and grind other knives down to this point.

(a) When all the knives are ground, feed wheel down .00025 to .0005 inch and traverse each knife in head one pass to compensate for diamond wheel wear.

(b) After feeding wheel down for each pass, jiggle the grinding motor with hand to prevent "double feeding". Too heavy a cut (over .001 inch) causes vibration and chipping of the cutting edge. You can hear the unit chatter when this occurs.

(c) It is not necessary that the grinding land on each knife cover the full thickness of the knife. Subsequent grinding operations will eventually do this. A small land the full length of each knife indicates concentricity within .0005 inch.

12. After grinding lightly, hone each knife with a 220 to 400 grit diamond hone.

13. Be sure setting collar plunger is holding knife against knife stop before making each pass.

Foreign Material Hazard in Wood

The first question in every woodworker's mind is what happens if we hit a nail with carbide knives? The best answer to this is that we have never had a set of carbide knives broken by hitting nails or other foreign material imbedded in the stock. Even knife chippage can be reduced

Fig. 8.—The nail imbedded in this white oak barrel stave was machined at 140 fpm stock feed without damaging the knives.

and in many cases eliminated entirely through proper carbide application. Fig. 8 shows a white oak barrel stave with a nail imbedded that has been machined at 140 fpm stock feed without damaging the knives.

Knife Breakage

Solid carbide planer knives have been broken in operation by chipbreakers on the machine getting into the knives. These broken knives can be repaired, however. Fig. 9 shows a set of 36-inch solid carbide knives broken and returned for repair. Fig. 10 shows the same knives completely repaired. These knives were originally installed on a rough surfacer in 1955. They are still in operation and giving a 20 to 1 tool life over high-speed steel knives.

Overcoming these problems has considerably broadened the field of application for cemented carbides in woodworking. Solid carbide knives that have for years been considered impractical are now being used as standard tooling on woodworking equipment. Machining operations such as rough surfacing, finish surfacing, molders, finger jointers, edge & veneer jointers, hand jointers, tenoners, and side matchers are utilizing carbide knives with outstanding results. Continued diligent effort on the part of carbide producers, and tool and equipment manufacturers to educate the industry in proper application of carbide tooling will accelerate the general acceptance of cemented tungsten carbide as an improved type of tooling for the woodworking fields.

Discussion

Richard V. W. Vaughn (Vaughn Co.): How is extended life of the knife obtained on edge jointer?

Mr. Weill: By moving the head to present a new portion of the edge to the cut.

Mr. Vaughn: How is the finish with these knives?

Mr. Weill: The finish is better than with steel knives.

Gordon L. Newhouse (Kittinger Co.): How do you eliminate chip breaker trouble?

Mr. Weill: The machinery maker will strengthen the machine to prevent the chipbreak bar from getting into the knives. Also, an automatic cutoff switch will help prevent jam-ups by stopping the machine and conveyor automatically.

M. H. Mater (Mater Engineering): What speed is used with carbide knives?

Mr. Weill: Steel speeds or more. Carbide knives are usually operated at steel knife speeds, although increased speeds can be used without burning carbide knives; examples are 3600, 5400, and 7200 rpm.

Mr. Mater: What are the feed speeds?

Mr. Weill: We generally use steel feed rates because of finish marks and machining characteristics of material being surfaced.

Mr. Mater: Do you use an old machine?

Mr. Weill: Yes, if the machines are in good condition.

N. G. Schuller (Fisher Price Toys, Inc.): What grit of dressing stone do you use for jointing?

Mr. Weill: 180 grit is used for jointing.

A. T. Patchen (Jamestown Veneer & Plywood): Our experience with carbide was poor due to bad fitting

Mr. Weill: Proper design, grade, and application techniques must be used on each application to insure proper performance of carbide knives.

Rex V. Reynolds (Kennametal, Inc.): You might watch machine conditions, particularly the grinding rail.

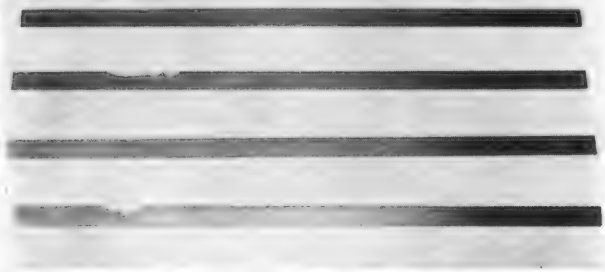

Fig. 9.—A set of 36-inch knives broken when a chipbreaker was accidentally fed into them. They were repaired and are again in operation.

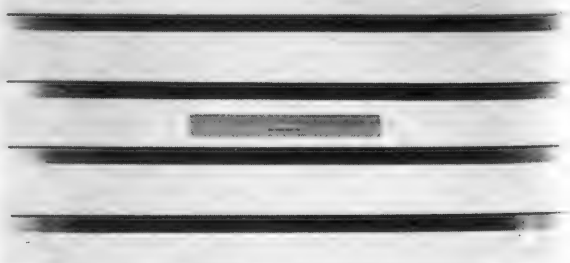

Fig. 10.—The same set of broken knives shown in Fig. 9 after they were repaired.

Active Carbon in America—1914 to 1957[1]

JOHN W. HASSLER

Industrial Chemical Sales Division, Director of Research, West Virginia Pulp and Paper Co., Tyrone, Pa.

The early development of active carbon was slow because little was known about the nature of adsorptions or potential applications. Research improved the carbon, and markets developed. Current production is 50,000,000 pounds annually. Applications include purifications of water, sugars, chemicals; concentration of antibiotics; prevention of color migration in plastic solids.

IT WAS THE "CLEAN STREAM MOVEMENT" that led to the development of the active carbon industry in America. Curiously enough, the material to be removed was later transformed into an agent universally used in water purification.

The offending material was "leacher", a charred waste of the soda pulp industry. From the beginning of the industry, this waste had been dumped into the stream. However, in 1911 new stream regulations made it necessary to end that practice, and a search was made to find utility for the wastes. When pulverized, the leacher resembles lamp black, and a plant was erected to process it into pigments for the paint and ink industries. Because of unsatisfactory color, the product was not acceptable for such use, and because it had no other apparent utility, the plant was on the verge of being abandoned. Then—quite by accident—it was found that the pulverized leacher had the ability to remove color from a solution. This turned the tide, but subsequent progress came slowly for in those days very little was known of adsorbents by industry. A start was made by marketing the leacher under the brand name of Filtchar as a replacement for bone char and fullers earth in the treatment of edible oils.

Although this product had decolorizing power, the quality was irregular; some batches were satisfactory, while others were not. At that time, active carbon was only a laboratory curiousity and practical methods of evaluation were non-existent. To meet this need, a study led to the development of a procedure that used an oil soluble dye. The test was then unique in that it placed a quantitative value on the absorptive power of carbon, which made it possible to select batches that would be satisfactory. In addition, the test supplied a tool to study ways of elevating the carbon quality. Within a short time, a more powerful carbon was being produced. This was prepared by roasting the acid-washed leacher in an atmosphere of steam at 800° C. in a rotary kiln.

Effect of World War I

The industrial development was uneventful before World War I. Then in 1915, an event that shocked the world brought fame to active carbon. World War I had become a purely defensive action, with the opposing armies land-locked in trenches. Seeking to break the impasse, the Germans made attacks with poison gases. The initial effects were terrifying, but lacked military value. By the time the Germans had learned to use war gases effectively, the Allies had developed protective measures in the form of active carbon in gas masks. Had it not been for this development, history might have followed a far different course.

At the conclusion of the war, many manufacturing operations adopted active carbon for purification; and on the other hand, many new producers of active carbon entered the field. The National Bureau of Standards has listed over 100 commercial brands of active carbon manufactured and marketed between World War I and 1945. Over 1,000 patents have been granted covering various methods of activation, but most of these represent modifications and variations of two basic processes, (a) pyrolysis, and (b) controlled oxidation.

In pyrolysis, the source material (Table I) is mixed with a suitable chemical agent (Table 2) and the mixture is carbonized between 400° and 700° C. Activation by controlled oxidation consists of subjecting a char at 600° to 900° C. to the action of oxidizing gases including steam, CO_2, and in some cases, air. The properties of the finished carbon are influenced by the type of source material used and by the conditions of activation, all of which account for variations between the different brands of commercial carbons. One may be better for purifying sugar solutions, and a different one superior for the treatment of pharmaceuticals.

Table 1.—SOURCE MATERIAL FOR ACTIVE CARBON. (Partial List)

Bagasse	Fruit pits
Bituminous coal	Kelp
Blood	Peat
Bones	Pulp mill waste
Cocoanut shells	Wood

Table 2.—CHEMICALS USED IN ACTIVATION (Partial List)

Calcium chloride	Phosphoric acid
Magnesium chloride	Sodium phosphate
Zinc chloride	Dolomite

The period following World War I was marked by intense competition. Of the hundred or more brands of commercial carbon developed during that period, only a few remain. The quest for survival led to continual advancement in the quality of active carbon. Within a space of 12 years, the process based on leacher experienced four basic changes, each of which necessitated complete rebuilding of production facilities.

But in spite of all efforts, the active carbon from leacher was gradually outdistanced by some of the newer competitive carbons. A careful study revealed that the steam activation which was in general use would not activate leacher to the same high quality that could be attained with other raw materials. Efforts were made to activate leacher by other processes then known, but none provided the adsorptive power necessary to remain competitive.

It began to appear that the original source material for active carbon in America had reached the end of the road. It was then discovered that, if leacher were ignited in air at 800 to 850° C. followed by roasting at a lower temperature of 500 to 700° C., an active carbon could be produced equal to the best and at a lower cost. Curiously enough, this two-stage process of air activation (which has been so effective for leacher) is of no practical value for activating other source materials so far studied.

Since the adoption of the two-stage process, no major changes have been made in processing leacher, but refinements in operating conditions and

[1] Presented at Session VIII, Chemical Utilization (Lignin), of the Eleventh National Meeting of the FPRS, held June 23-28, 1957, in Buffalo, New York.

Author: John Hassler received his education at Pratt Institute and the University of Maine. Author of two books and over 15 papers on carbon and related subjects, Hassler developed the original process to manufacture active carbon in the United States.

equipment design have resulted in a general elevation of quality.

The improvement in manufacturing processes has been paralleled by the development of newer and wider markets. In 1956, over 100 million pounds of active carbon were produced and marketed in the United States, and of this approximately one-half was manufactured from pulp mill waste leacher. The markets include many diverse applications. The industrial utility of active carbon presents many facets, but all spring from a basic property, adsorptive power. And so, a good way to begin the discussion of markets is to describe adsorption.

The Nature of Adsorption

Adsorption represents the ability of a solid to pull a substance out of a gas or liquid and bind it to the surface. The large surface area of active carbon 1,000 to 2,000 square yards per gram) provides ample space on which substances can be adsorbed. But extent of surface alone does not explain the specificity so often encountered, such as the fact that one brand of commercial active carbon is better for water purification, another for raw sugar, and still another for streptomycin. An interpretation is suggested by analogous behavior found in solutions, in which the solubilities of dissimilar substances vary from one solvent to another. Supporting this analogy is the fact that the tie binding an adsorbed molecule is similar to the bond that holds molecules in solution. For the present purpose, an adsorbent surface may be considered as equivalent to a two-dimensional solvent whose specific properties depend on the method used for activation.

The chemical nature of the substance to be adsorbed is an important factor. For instance, under similar adsorption conditions, phenol is more adsorbable than acetic acid. However, the extent to which any given substance is adsorbed depends on the conditions under which adsorption is conducted. Thus, raising the pH from 3 to 12 reduces the adsorption of phenol (Table 3), and the use of a different solvent, (for example benzene in place of water) can result in even greater reduction. This ability to guide an adsorption into desired channels has extended the utility of active carbon and made it practical to reach markets not visualized a few years ago. Even so, only part of carbon's full potential has been uncovered. Much progress has been made, however, and the use of active carbon has come a long way from the early days when it was confined to decolorization, a limitation that led to the general use of the term "decolorizing carbon".

Table 3.—ADSORPTION FROM SOLUTIONS CONTAINING 1 GRAM PHENOL PER LITER

Solvent	pH	Milligrams phenol adsorbed per gram carbon A
Water	3	176
Water	12	52
Benzene	--	10

The first break-out from this limitation was the development of vapor-phase adsorption in such application as gas masks and solvent recovery. A few years later, active carbon entered the water-purification field for the removal of tastes and odors, a field in which carbon continues to reign supreme.

During this same period, it came to be recognized that adsorbable impurities can cause objectionable properties in products and difficulties in processing, such as foaming, poor filterability, haze formation, emulsions, inadequate crystallization, and short shelf life. Since these unwanted characteristics are due to adsorbable impurities, they can usually be corrected by treating the processing liquors with active carbon.

The general basis of the improvement can be illustrated by the crystallization of sucrose from a raw syrup. When sugar crystals begin to form in a raw syrup, the "color" molecules present are adsorbed on the crystal surface. This blanket prevents sucrose molecules in solution from reaching the crystal, which, as a consequence, does not grow. If carbon is added to the syrup, the color molecules migrate to the carbon surface, leaving a clean surface on which sucrose molecules can be deposited from solution.

As the many and varied benefits accomplished by removal of adsorbable impurities were more widely utilized, manufacturers of active carbon realized the need of a term other than "decolorizing carbon" to dramatize the versatile properties. This resulted in slogans such as Active Carbon—the Modern Purifier. Although the term decolorizing carbon still persists in some quarters, the value of other purification properties has become more clearly recognized and today is a primary basis for acceptance in some markets.

In fact, recent industrial developments seem to require an even broader description for active carbon than provided by the term purification.

Absorption – Desorption

In one such development, active carbon is employed as a reservoir to maintain vapor and solution concentrations at required levels. This use is based on the fact that a substance in the adsorbed state becomes less volatile and less soluble. This behavior is utilized in applying the new systemic insecticides. These powerful agents are quite soluble, and in strong concentrations damage growing plant life. Consequently, the total quantity of insecticide necessary for seasonal protection cannot be added in a single application—that is, not under ordinary conditions. But in a mixture with carbon, the adsorbed insecticide is released gradually and in quantities just sufficient to maintain the required concentration in the environment.

It will be apparent that the foregoing application of carbon as a reservoir implies the ability of carbon to release an adsorbed substance, a behavior knowns as desorption. The use of adsorption combined with desorption has received much attention as a means of reclaiming trace materials. The mechanism of the process can be explained by reference to the data shown in Table 3. When that adsorption is conducted from an aqueous solution at pH 3, each gram of carbon holds 176 milligrams of phenol. If the carbon is separated from the aqueous phase and placed in benzene, then according to Table 3, it will hold only 10 milligrams per gram. Theoretically, the difference between 176 and 10 milligrams will be desorbed.

A classical illustration of the industrial use of adsorption-desorption is provide by the original process used for manufacturing penicillin[2]. In this process, active carbon was added to the fermented broth containing about 30 ppm. of penicillin. After removal from the broth, the carbon was extracted with acidified methanol, which eluted the adsorbed penicillin in a relatively concentrated form.

The applications described thus far are limited to gaseous or liquid systems. More recently, consideration has been given to possible uses of active carbon in plastic solids. A major development involves prevention of color migration such as causes the discolorization of white-sidewall tires. These tires are formed by placing a thin layer of white rubber over a dark carcass. Color bodies in the carcass normally migrate to the sidewall and result in discolorization. By incorporating active carbon in the underlying carcass, the migrating color bodies become attached to the carbon particles and are thereby prevented from reaching the white sidewall.

Summary

The examples cited of carbon application have been chosen primarily because they serve to illustrate the versatility of active carbon. No attempt is

[2] This process, which was most important in the early development of penicillin but has since been replaced by other methods, still remains as a classic illustration of the use of adsorption-desorption.

made to encompass all applications or even all types of use.

In relating the accomplishments, it is fitting to express recognition of the extent of contributions made by those not directly connected with the active carbon industry. Many applications have originated and been developed by workers in other fields, workers with the vision and imagination to utilize the versatile properties of active carbon to improve products and processes they were developing.

This has been the history of carbon for penicillin, streptomycin, antistaining of plastics, and numerous other applications. Such contributions have come because of intelligent self-interest, but the net effect is equivalent to having silent partners in many other research groups who are creating new markets for active carbons.

On the other side of the coin is the fact that most new developments must be surrounded with secrecy, which eliminates any opportunity for direct participation by outsiders, including research workers in the active-carbon industry. Consequently, for the future the active-carbon industry should direct much of its research efforts to the development, collection, and publication of data on fundamental aspects of active carbon. In addition, the industry must maintain a flexibility of mind and processing, and be ready to furnish new types of carbons with properties necessary to reach into new and different markets.

Effect of Incising on Penetration of Creosote in Japanese Cedar Poles[1]

MORIKAZU HATTORI[2]
Chief Engineer, Sanyo Wood Preserving Co., Hiroshima, Japan

Japanese cedar poles treated with as much as 10 pounds of creosote per cubic foot were failing by internal decay at the groundline. Effect of incising was studied in an attempt to improve penetration in the middle sections of poles. Both penetration and uniformity of distribution were improved without loss in strength of poles.

THE PROCEDURE KNOWN AS INCISING, which consists of mechanically puncturing many holes into woods that are difficult to impregnate in order to improve penetration and distribution of preservatives, is an old one but one that has not been heretofore practiced to any extent in Japan. This paper describes the application of the incising process to one species of wood in Japan. The steps leading from recognition that incising might overcome problems met in the preservative treatment of Japanese Cedar, *Cryptomeria japonica,* through experimental treatments of the incised wood, and finally to successful commercial use of the incising procedure should be of interest to many FPRS members who are faced with similar problems in their utilization of native species, particularly in newly developing forest products industries in areas that have hitherto been undeveloped.

The problem presented itself in the observation that creosote-impregnated Japanese cedar poles were found to be failing by internal decay at the groundline in spite of the fact that the wood was being treated to retentions of 10 pounds or more of creosote per cubic foot of wood. Examination of the poles showed that most of the creosote was confined in the end sections of the poles, while the sections toward the middle had only shallow penetration. Absence of ray tracheids, which in many conifers serve to conduct preservatives in radially from the surface, probably accounts for the fact that most of the penetration in Japanese cedar takes place from the ends.

Experimental

Experimental work on the effect of incising on the penetration of creosote in Japanese cedar poles included first, a determination of tangential penetration from naturally occurring seasoning checks, and second, of longitudinal penetration from a spiral saw cut made on the poles. Results of these tests were used as a basis for setting up the pattern of incisions which these tests indicated would give the greatest improvement in penetration. After this, a number of poles were incised according to this pattern, and the effect on penetration was studied. Strength tests were also run on the incised poles, since the question of the effect of incising on strength always arises among engineers in areas where incising has not been practiced previously.

For determination of the tangential distances that creosote could be expected to move from the incisions, 27 posts were taken at random from incoming shipments. Material used in all of these tests was received freshly cut. All of it was obtained in the Hiroshima area of the main island of Japan. The posts were 14 feet long and had a top diameter of 4¾ inches. Nine of the posts were treated in green condition, nine after about 2 months seasoning, and nine after about 5 months seasoning. The posts were treated for one hour under a pressure of 114 psi after filling the cylinder at atmospheric pressure (empty-cell process without initial air, known in the U. S. as the Lowry Process). The treating temperature was 140° F. The creosote used had the following composition:

Water, per cent by volume	1.0
Material insoluble, per cent by weight	0.3
Specific gravity at 40°C/20°C	1.036
Distillate to 210°C per cent by weight	3.0
Distillate to 235°C per cent by weight	13.0
Distillate to 270°C per cent by weight	36.6
Distillate to 315°C per cent by weight	64.5
Distillate to 355°C per cent by weight	86.5
Tar acids per cent by volume	6.1

After treatment, the posts were cut at the midpoint and 37 to 42 measurements were made of the tangential movement of creosote from the naturally occurring seasoning checks. The results of this test are shown in Table 1.

Since the average tangential distance of creosote movement was 0.35 inch, it would be expected that an incising pattern with a spacing of not more than 0.70 inch across the grain from hole to hole would result in uniform penetration in the outer layer of the poles to the depth of the incisions.

[1] A contributed paper, received August, 1957.
[2] The assistance of Monie S. Hudson, consulting chemist, Spartanburg, S. C., in preparing the paper for publication is gratefully acknowledged.

The Author: Mr. Hattori is a graduate of the School of Technology, Tokyo University. He is a member of the Executive Committee of the Wood Preservation Division, Japan Society of Wood Technology, and is second vice president of the Engineering & Research Division, Wood Preservation Society of Japan. Hattori is also on the Executive Committee of the Japan America Fellowship Association in Hiroshima.

Table 1.—TANGENTIAL PENETRATION OF CREOSOTE FROM NATURALLY OCCURRING SEASONING CHECKS

Number of posts	Initial weight lbs/cu. ft.	Initial moisture content, %	Creosote retention, lbs/cu. ft.	Average tangential penetration from seasoning checks, inch	Standard deviation, inch
9	43	91	5	0.44	±0.63
9	34	51	7	0.38	±0.63
9	27	20	10	0.31	±0.63

Table 2.—LONGITUDINAL PENETRATION OF CREOSOTE FROM SPIRAL SAW KERF

Number of posts	Initial weight lbs/cu. ft.	Initial moisture content, %	Creosote retention, lbs/cu. ft.	Average longitudinal penetration from spiral saw kerf, inches	Standard deviation, inches
6	50	122	4	9.13	±2.7
6	40	78	6	10.53	±3.5
6	32	42	8	10.88	±3.1
6	27	20	9	8.31	±3.1

For the test on longitudinal penetration, 24 of the 4¾-inch by 14-foot posts were used. They were divided into four groups of six posts each. One group was treated while green. The other three groups were seasoned for varying lengths of time ranging from 2 to 5 months. Before treatment, the posts were cut with a spiral groove 0.06 inch in width and 0.66 inch in depth. The pitch of the spiral was such that a complete revolution was made around a post in a distance of 3 feet.

The posts were impregnated with creosote under the same treating conditions that were used in the test for tangential penetration. After treatment, the posts were sectioned at the midpoint and the bolts formed were split lengthwise. The distance that the creosote traveled with the grain of the wood from the spiral saw-kerf was measured at 5 to 8 points on each post. Results of this test are shown in Table 2.

This study showed an average overall longitudinal penetration of 9.53 inches, so it was concluded that a pattern of incisions with a distance of spacing lengthwise to the grain of the wood of not more than 19.1 inches (2 times 9.53) would be suitable to assure lengthwise merging of zones of penetration from any two incised holes.

Effect of Incising on Impregnation of Air-Seasoned Wood

Having developed the above information that the incisions should be in a pattern roughly ¾ inch apart across the grain of the wood and about 19 inches apart lengthwise to the grain, the next step was that of treatment of some incised and unincised poles and comparison of the results as to retention and penetration. Six thoroughly air-seasoned poles were used in the first comparative test on incised and unincised poles. These poles were 20 feet long, with top diameters of 4¾ inches. Three of the poles were incised before treatment.

For practical reasons, the pattern of incising was changed from the ¾-inch by 19-inch spacing indicated by the previous tests. Since it was planned to cut the 20-foot poles after treatment into sections with a length of 1 foot for study of penetration and distribution, it was concluded that a lengthwise spacing between holes of about 1 foot would be best. With the longitudinal distance being decreased from 19 inches down to 12, the lateral distance between holes was increased from ¾ inch up to 1 3/16 inches to give an adjusted pattern in which the relative distances apart were of the same order as the ¾- by 19-inch spacing. The six poles were then treated with creosote in the same manner described for the first two charges above.

After treatment, each of the poles was cut into 20 sections one foot long. Each of the sections was weighed, and its computed untreated weight was subtracted from the treated weight to obtain the retention of creosote in the section. The average retention for the whole pole was determined from the weights taken before and after treatment. Retention found in each of the 1 foot sections was divided by the average retention for a section of that size based on the whole pole weights. This retention ratio was expressed as a per cent. Data obtained in this way for the incised and unincised poles were averaged. The results are plotted in Fig. 1. This figure shows that distribution of creosote in the incised poles was much more uniform than in the unincised.

After the 20 twelve-inch sections from each pole were weighed, each end of each section was examined to determine the total area of sapwood visible on the cut faces and also to determine the percentage of this area that was penetrated with creosote. The average results for the three incised poles and for the three unincised poles are shown in Fig. 2. The sapwood penetrated in the unincised poles will be found to average about 45 per cent when the two sections at the extreme ends of the poles are excluded. The incised poles show an average penetration of about 65 per cent.

Effect of Incising on Impregnation of Artificially Seasoned Wood

A series of charges were next run to determine the effect of incising on Japanese cedar prepared for impregnation by two of the widely used methods of artificially conditioning wood prior to preservative treatment. The methods were the steam and vacuum treatment and the boiling-under-vacuum treatment (Boulton Process). For purposes of comparison, several charges conditioned by air seasoning were run also.

Eighteen of the 14 foot by ¾ inch incised posts were used in this test. Twelve of the posts were air seasoned. These were treated with creosote in four charges by the empty-cell process as in previous charges.

The posts for the Boulton treatment and the steam and vacuum treatment were green. In the steam and vacuum treatment, three posts were subjected to steam at 248° F. (14 psi) for 6 hours, followed by 2 hours vacuum at 28 inches of mercury. The three posts conditioned by the Boulton Process were submerged in creosote at

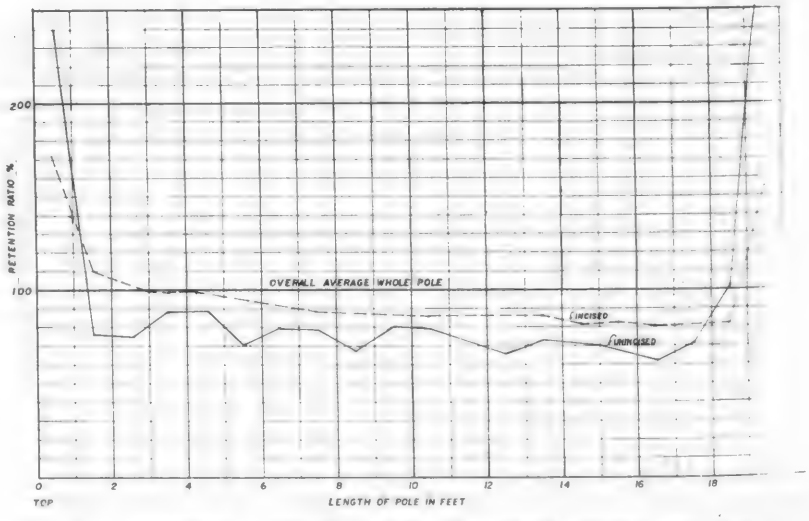

Fig. 1.—Distribution of creosote in incised and unincised Japanese cedar poles.

Table 3.—PERCENTAGE OF SAPWOOD PENETRATED IN POSTS THAT WERE AIR-SEASONED, STEAM-AND-VACUUM TREATED, AND BOULTONIZED

Number posts	Initial weight, lbs/cu. ft.	Initial moisture content, %	Preliminary conditioning	Creosote retention, lbs/cu. ft.	Percentage of sapwood in cross section	Percentage of sapwood penetrated
3	42	87	air seasoned	5	65	14
3	34	51	air seasoned	7	65	17
3	30	33	air seasoned	10	62	39
3	27	20	air seasoned	8	72	30
3	51	127	steam and vacuum	10	--	65
3	53	136	boiling under vacuum	14	--	79

Table 5.—CREOSOTE RETENTION IN INCISED, AIR-SEASONED POLES COMMERCIALLY IMPREGNATED BY THE EMPTY-CELL PROCESS

Number charges	Preliminary conditioning	Initial weight, lbs/cu. ft.	Initial moisture content, %	Fraction defectives[1], %	Creosote retention, lbs/cu. ft.
75	Air seasoning	28	26	11.6	10
75	Air seasoning	30	33	12.1	10
55	Air seasoning	32	42	12.1	10
35	Air seasoning	34	51	12.4	10
30	Boiling under vacuum	46	105	5.0	22

[1] Per cent of poles not meeting Japanese Industrial Standard A9101.

Table 4.—STATIC BENDING STRENGTH OF INCISED AND UNINCISED JAPANESE CEDAR POLES

Pole No.	Weight, lbs/cu. ft.	Moisture content, %	Density, annual rings per inch	Retention of creosote, lbs/cu. ft.	Modulus of rupture in static bending, lbs/sq. in.
		INCISED POLES			
54	25.8	15	15	12.3	5463
52	25.9	15	13	9.2	6559
29	26.0	16	10	13.2	4696
47	26.1	16	13	10.4	5658
46	26.8	19	10	16.4	5298
33	27.0	20	10	8.4	4826
43	27.0	20	10	9.6	6279
41	27.6	23	15	13.3	6135
49	28.8	28	10	15.6	4350
36	28.9	29	13	9.8	5410
14	30.5	36	13	12.3	4207
Average	27.3	22	13	11.4	5358
		UNINCISED POLES			
50	25.4	13	13	12.6	6130
40	25.9	15	10	12.9	5827
19	26.6	18	15	8.2	4792
59	26.8	19	10	13.5	5428
53	26.5	18	10	16.2	4326
56	26.9	20	10	17.1	4647
58	27.4	22	10	12.0	6262
37	27.8	24	13	9.2	5126
20	28.8	28	13	9.8	5518
16	29.5	31	10	10.2	4680
57	30.0	33	10	10.9	4799
Average	27.4	22	13	12.0	5230

184° F. under a vacuum of 28 inches of mercury for 6 hours. After the charges were conditioned, they were impregnated with creosote in the same manner as the air-seasoned charges, except that the creosote temperature was 151° F. on the charge that had been steamed, and 184° F. on the Boultonized charge, and 28 psi of initial air was applied before filling the cylinder. The final vacuums after impregnation of these last two charges were left on them over night.

After treatment, the posts were cut to determine penetration. The results of these tests are shown in Table 3.

This table shows that retention and penetration in the incised and artificially seasoned green poles was much better than that obtained in the incised air-seasoned poles when they were impregnated under the same conditions. It may be noted that the percentage of sapwood penetrated in these air-seasoned posts is much less than that shown for the air seasoned poles in Fig. 2. This is accounted for by the fact that the latter were thoroughly air seasoned while, as will be seen from the moisture-content values, most of the air-seasoned poles in the above table were well above 30 per cent.

Effect of Incising on Strength of Wood

Twenty-two of the 20 foot by 4¾ inch poles were used to determine whether the incising had any effect on the strength of the wood. Eleven of the poles were incised. The incising pattern was 19 inches between holes in the fiber direction, and 1 3/16 inches in the direction across the grain. The poles were impregnated together with the 11 unincised poles by the same process used on the previous charges.

After treatment, the poles were broken by static bending as cantilever beams. Butts of the poles were fixed in a crib with the poles lying in a horizontal position. Load was applied to the top by means of a winch and cable; a dynamometer was used to read the load. The loading rate was approximately 3 pounds per second.

The results of this test are shown in Table 4. Since no significant difference in modulus of rupture for the two groups of poles is apparent, it may be concluded that the incising had no effect on the strength of the wood.

Incising Applied to Commercial Treatments

The results of 240 commercial treatments of incised, air-seasoned, Japanese cedar poles impregnated by the empty-cell process without initial air are summarized in Table 5.

The last 30 charges shown in this table were made up of green poles. They were conditioned by the Boulton Process and then impregnated with creosote by the full-cell or Bethell Process. The Boulton Process has not yet been accepted as a standard in Japan, but experiences of early failure of air-seasoned creosoted poles have indicated that insufficient retention was the cause. These green charges were run to determine whether Boultonizing followed by full-cell treatment would also help to improve the retention. The table shows that the retention obtained in the Boultonized, full-cell treated poles was double that obtained in the air-seasoned poles treated by the empty-cell process. Moreover, the number of Boultonized and full-cell treated poles that required re-treatment was less than half that of the air-seasoned group treated by the empty-cell process.

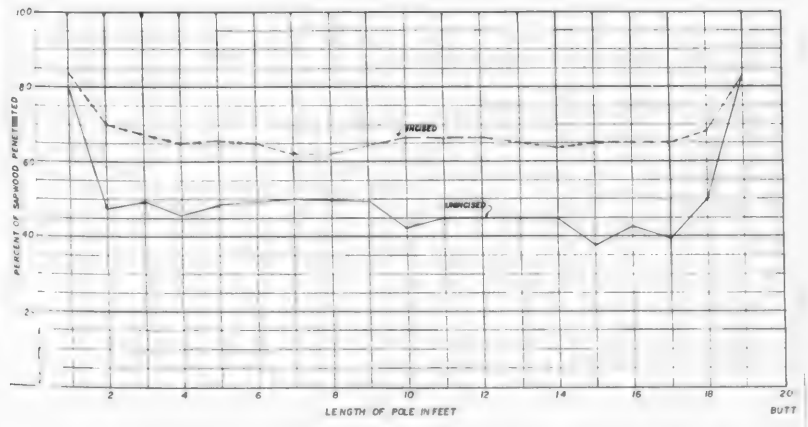

Fig. 2.—Penetration of creosote in incised and unincised Japanese cedar poles.

Utilization of Waste Material in a Redwood Mill

J. J. DeFino, Hammond Lumber Co., Eureka, Calif. Presented at the Northern California Section Meeting, Sept. 14, 1956.

Approximately six years ago, the Hammond Lumber Co. began experiments on edge and end gluing to reduce mill waste by salvaging short pieces of lumber. Up to this time, short trim ends had been hogged for fuel or burned. Work was also started on the development of wide boards from narrow strips. Success in making end-glued boards was contingent upon finding a type of joint that would lend itself readily to mass production and yet would retain strength properties similar to clear wood. A finger-type joint was developed that lends itself readily to mass production and has a strength of 50 to 60 per cent of clear wood.

The firm's salvage mill has become a good source of supply of short green lumber that can be processed for finger jointing. Sawmill leftovers such as green trim ends, two to four feet in length, are being used. Resawed to 1 inch thickness, these boards are air dried for three to five months, kiln dried to 8 per cent M.C., and processed for finger jointing. Recovery in board feet on the green sawmill trim ends has been approximately 60 per cent of the gross footage salvaged, while dry trim ends run 65 to 70 per cent.

All short pieces come to the Glue Board Department kiln dried to 8 per cent M.C. The rough dry boards are surfaced to 27/32 inch, trimmed of defects on a double-end trimmer, and ripped to the desired width. End jointing is accomplished by means of two single-end matchers. The pieces are end jointed at a rate of approximately 25 boards per minute. This can be increased up to 48 under certain conditions. The cutter head speed is 7200 rpm. Some chipping may occur, but no burning.

As the finger-jointed boards leave the matcher, they pass through an electronic moisture detector on a continuous belt conveyor. If a board is too wet, it trips a relay and this energizes a solenoid that in turn energizes a metal shunt that kicks the board off the production line. A revolving disc spreads glue on one end of each board. A fortified 50/50 melamine and urea hot press, boil-proof glue is used.

After it is spread with glue, each joint is inspected and placed on edge on a chain conveyor that moves toward the R. F. Field. To insure a tight joint, the boards are forced together by use of a pusher unit. One short board is retarded in its movement toward the Field by a hold-back clamp while the board immediately behind is forced ahead. This occurs by means of two traveling belts that exert a vice-like force to the faces of the boards and thus force the joint tight into the joint of the board ahead. Retarding action is accomplished by an air clamp exerting pressure on either face of the board. The endless board then passes into the R. F. Field where the joints are dried. It travels through the electronic field at 30 to 50 lineal feet per minute, depending on the width of lumber. A traveling cutoff saw cuts the board to the desired length as it leaves the field.

Edge-glued stock is manufactured from either finger-jointed stock or narrow-width Clear lumber. Before it is edge glued all stock is run through a Diehl Model 99 straight-line ripsaw to insure parallel and smooth edges. Widths are segregated on a table ahead of the R. F. Field. Each narrow board is placed on a traveling belt and the edge is spread with glue as it passes the glue spreader. The narrow boards are assembled in proper width and enter the R. F. Field. Traveling clamps exert pressure on the outside edge of the wide board as it passes through the Field at about 10 to 12 feet per minute. The wide boards are then trimmed and sanded to order.

Gang Saws for Log Break Down

Harold Swanson, Dominion Bridge Co., Ltd., Vancouver, B. C. Presented at an Inland Empire Section Meeting, September 1957 at Omak, Wash.

As a breakdown machine for round logs, gangsaws can be called plain round log gangsaws. In considering the use of gangsaws, it is necessary to take into account the species of timber available, diameter of the logs, size and grade of lumber than can best be marketed, and available capital.

A round log gangsaw is recommended for a mill that has 30 to 50,000 bd. ft. of small logs from 6-inch to 18-inch diameter available daily, and enough capital to finance a modern gangsaw mill containing a log and cant gangsaw and auxiliary equipment. The round log gang would cut one or more cants in the center of the logs and boards on the side. The cants would go to a cant gangsaw, where they would be sawn into boards.

By using a tandem arrangement, upkeep can be kept low because there is less strain on the machine when fewer saws are used in the logging frame. If done properly, log sorting can improve both output and recovery and allows for setting the saws for larger cants in larger logs. Two or three sorts would be all that are necessary for efficient operation.

A round log gang is recommended where small logs are available in quantity and the species is such that little or no higher grade lumber could be taken out. A gangsaw installation will at least double production per manhour in small timber compared to conventional headsaws.

In Scandinavian mills, logs down to 9 inch diameter are sorted every inch and logs under 9 inch diameter every ½ inch. The saws are placed in the frame to recover every bd. ft. of lumber available. This type of sorting is, however, not practical in most mills on this continent, but logs from 6 inch diameter to 18 inch diameter should definitely be sorted in 3 lots, 6 inch to 9 inch, 9 inch to 12 inch, and 12 inch to 18 inch.

Seventy-five per cent of all the mills large enough to warrant a gang installation would be well advised to install a cant gangsaw in combination with a hand or circular headsaw. Installation of this type would allow a mill to saw any size logs the headsaw is able to handle without sorting; to recover any available grade out of the log before turning cant over to the gangsaw; to raise the production of the mill 50 per cent in many instances; to produce specified widths of lumber in large quantities without jeopardizing the overrun; to cut accurately dimensioned lumber;and to get the highest possible recovery due to the possibility of following the bend of the cant in gangsaw.

Such a mill will produce 40 to 70,000 bd. ft. of lumber per 8-hour shift, depending on the average diameter of logs, species of timber supply, and dimensions manufactured. With an addition of a round log gang the capacity of the mill would be 80 to 100,000 bd. ft. per shift.

A round log or cant gangsaw would be very advantageous in 1) a mill with a high percentage of small logs under 10-inch diameter where a split top feed roll gangsaw could cut two logs side by side, 2) with a veneer plant for cutting cores, and 3) when sawing 8 foot logs into 2 inch lumber.

Around the World in Forest Products Research and Development

Scanning World-Wide Forest Products Publications

Germany

On the Use of Nails for Pressing Glue Joints in Wood Constructions. Hans Kolb. *Holz*, V. 16, No. 1.

The question whether nails can be used for the manufacture of good glue bonds instead of the usual pressing tools was investigated. The results are as follows: The variation of pressure forces obtained by nails with the same diameter is to a large extent contingent on the structure of the wood. The shear test on small specimens showed a clear decrease in strength of the nailed products compared to the products pressed by clamps. The main tests that were conducted on three-piece rectangle–girders, I–girders and laminated-girders proved that the bonding strengths can be achieved by a careful application of the wire nails. Thus it can be stated that it is possible to produce the required pressure by means of wire nails when gluing with filling glues. It must be noted, however, that 1) the average moisture content of the specimens was 12 to 15 per cent, 2) the specimens were chosen and worked with special care, and 3) the specimens were comparatively small with regard to conditions prevailing in practice.

Norway

The Influence of Resinous Wood on Hardboard Properties. A. B. Anderson and K. Helge. *Norsk Skogindustri*, No. 1, 1958.

Some years ago, it was found that when the heartwood of extractive—or resinous-rich pine wood from ponderosa pine (*Pinus ponderosa*) or southern pine (*P. echinata* or *P. palustris*) was incorporated in the hardboard composition, along with normally used wood chips, the resulting hardboard had good strength properties and high resistance to water absorption, without the adding of sizing agents or subsequent heat-treatments as practiced in the Scandinavian countries.

The influence of some resinous wood in Norway on hardboard properties was tested. The wood containing most resin in Norway is the stump of mature pines (*Pinus sylvestris*). The heartwood from the butt log portion of freshly felled mature pine trees was employed. The heartwood was found to contain about 15 per cent ethyl ether soluble extracts (dry wood basis).

ANTONIO DE LAS ALAS (center), former House Speaker and Finance Secretary of the Republic of the Philippines, was re-elected last March as President of the Philippine Lumber Producers' Association at the organization's Annual Meeting held at the Philippine Columbian Clubhouse. Mr. Alas is shown with the Board of Directors of the Association.

Chemical analyses made of the ether-soluble extract showed that the predominating component in the heartwood extract is resin (rosin) acids, while free fatty acids are most prevalent in the sapwood extract. In general, the ratio between these components is somewhat comparable to what is present in ponderosa pine sapwood and heartwood nonvolatile ether-soluble extract. The pine heartwood used in this investigation had about 1/3 less steam volatile terpenes than was found in ponderosa pine heartwood used in aforementioned hardboard experiments.

Six compositions were prepared and processed into 1/8 inch hardboard. These were 1) 100% pine heartwood, 2) 75% heartwood and 25% sapwood, 3) 50% heartwood and 50% sapwood, 4) 25% heartwood and 75% sapwood, 5) 15% heartwood and 85% sapwood, and 6) 100% sapwood. In preparation of the hardboard from each composition, one-half of the boards were prepared without sizing agents, while the remaining boards were prepared with 1% alum (dry pulp basis). Half of each board was heat-treated at 160°C., for 3 hours, while the remaining half received no heat-treatment before testing.

Water absorption values given are based on the per cent of water absorbed after the board had been conditioned to equilibrium moisture content.

None of the boards that were not heat treated had water absorption values that were low enough to meet specifications. The board with the highest strength value was produced from 100% heartwood, and strength values decreased approximately proportionally to the amount of resinous heartwood present in composition. The water absorption values (thickness swelling) likewise decreased as the amount of heartwood was increased in the composition.

The resinous wood hardboards did not impart the same properties as was the case with resinous ponderosa pine heartwood. This difference in behavior is believed to be caused by the greater quantity of volatile terpenes present in ponderosa pine.

All boards, after heat-treatment, had lower water absorption values with correspondingly low thickness swelling. There was a considerable increase in strength, demonstrating that the heat-treatment step, as practiced in Scandinavia, is beneficial in improving board quality.

There was a considerable lowering of strength properties when alum was added. None of the boards that were not heated had a marked drop in water absorption values. After heat treatment, each of the boards took on added strength and greater resistance to water absorption, again demonstrating the effectiveness of heat treatment.

Since the hardboard produced from 100% sapwood, which contained only 0.3% rosin acids, had good water resistance after heat-treatment, even without alum, it is believed that the extractives play a minor role here during the heat-treating cycle. This would suggest that the hemicellulose component in the cell wall is perhaps more responsible for decreasing water absorption.

Abstracts From Current World Literature

Fire Resistance

Fire: Materials and Structures. Building Research Station Digest No. 106, Building Research Station, Garston, Herts, Order from British Information Services, 30 Rockefeller Plaza, New York 20, N. Y., 1958, 6 pp, 10¢.

This report is concerned with the combustibility of building materials, flame spread on surfaces and the fire resistance elements of structure. Various types of flooring, wall and ceiling linings, roofing, etc., are discussed, and there is a table showing spread-of-flame classification of combustible wall and ceiling finishes. Another table shows performance of various types of boards tested in fully-lined rooms. Other topics covered include the combustible contents of buildings and the general subject of fire resistance of different types of construction. [BRI Abstracts, March 1958]

Particle Board

The L. K. process. *In Holz als Roh-und Werkstoff*, Vol. 15 No. 8, Aug 1957, p. 354.

This is a process which produces hollow forms from chipboard in one continuous operation. Chips pass automatically from the chipping machine through the dryer and the adhesive mixing chamber. The pressing plant shown in a diagram explains the various phases of forming. In the plant itself the chips are loosely loaded into the desired shape, pressed and hardened. While this takes place new shapes are being made ready. Thirty to 240 pieces can be pressed per hour according to the size of the plant. The containers can also be lined with a veneer inside and out in a separate process.

Since the shapes are interchangeable, more than one shape can be pressed at a time. Crates, drawers, and small pieces of furniture can be manufactured by this process. [F. D. C. Tech. Bul. V. 7, No. 38]

Finishing

Kostiuk, E. The use of polyester resins in wood finishes. Proceedings of 4th Fatipec Congress, Lucerne Verlag P. G. Keller, Winterthur 1957, pp. 101–108.

Wood being a very porous heterogeneous material, sensitive to moisture containing also various foreign matter, the usual furniture (nitro-cellulose) lacquers often have a tendency to split and crack owing to their lack of tensile strength. The varnishes containing polyester resins are less inclined to be brittle and their high concentration of film-forming matter has the advantage of reducing the number of coats to be applied. It is pointed out that soluble matter of a foreign nature contained in wood, as well as the impregnation of various solutions, can retard or impair the drying of polyester varnishes. (In French, Eng. abst.) [F. D. C. Tech. Bul. V. 7, No. 38]

Wood Chemistry

Björkman, Anders. Lignin and lignin-carbohydrate complexes; extraction from wood meal with neutral solvents. *Ind. Eng. Chem.* 49, no. 9: 1395–8 (Sept. 1957).

Thorough subdivision of wood by grinding in a vibrational ball mill was partly successful in facilitating the extraction of lignin with neutral solvents (toluene, cellosolve, etc.). Approximately half of the lignin could thus be extracted, depending on grinding conditions and other factors. Subsequent extraction of the milled wood lignin (I) with dimethyl formamide or dimethyl sulfoxide yielded lignin-carbohydrate complexes (II). Extraction and analytical studies on both (I) and (II) indicated that one half of spruce-wood lignin occurs free and the other half combined with hemicellulose (but not with cellulose). Hydrogen bonding and related physical phenomena may play a greater role in this combination than do covalent bonds. [Bul. Pap. Chem. V. 28, No. 3]

Sanding

Brown, L. G. Automatic sanding. American Society of Mechanical Engineers, Paper No. 57, WD1-6, May 1957, 9 photographs, 4 pp.

A bottleneck has been created in sanding departments by the increase in wood machining speed and improved faster drying finishing materials.

The mechanization of sanding operations has not kept up with mechanization in other sections of the woodworking industry.

During the past nine years improvements have been made in coated abrasives which give longer effective cutting life. Improvements in machine design include endless bed drum sanders which will produce more uniform and higher quality finishes and the use of endless bed feeds to vertical belt sanders having a contact drum or platen. Edge sanding can now be performed on narrow belt sanding machines arranged to sand two parallel edges simultaneously. The introduction of serrated contact belts and drums has increased the effectiveness of abrasives and the use of backstand arrangements has resulted in higher production on open drum sanding operations.

In most sanding operations work has still to be fed by hand and a considerable amount of manual skill is employed in finishing shaped work.

Three methods of production layout described deal with different types of factory and production schedules. [F. D. C. Tech. Bul. V. 7, No. 38]

Properties

Stamm, Alfred J. Adsorption in swelling versus non-swelling systems. I. Contact area. *Tappi* 40, no. 9: 761-5 (Sept. 1957).

Adsorption of vapors on nonswelling solids is confined to pre-existing surfaces. On certain swelling solids, however, the adsorption may be more than 100 times that which would occur on the pre-existing surfaces. This increased adsorption involves the formation of molecular contacts between the solid and a condensed vapor where only contacts between the structural units of the solid itself existed previously, thus forming a solid solution. Data are presented to justify the application of the Brunauer, Emmett, Teller (B.E.T.) theory for determining the surface area of powders to the calculation of the effective area of molecular contact between a solute and a solvent in solutions and between a gel and an adsorbed vapor in swelling systems. The effective area of molecular contact in solutions thus calculated yields a reasonable result, one to four solvent molecules being directly associated with each solute molecule. An aerogel of cellulose (made by replacing water with a volatile nonswelling liquid followed by flash evaporation of the liquid) has a surface area, determined by low-temperature nitrogen adsorption, that is of the same order of magnitude as the area of molecular contact with water calculated from water-adsorption isotherms for the unexpanded gel. The constant C in the B.E.T. equation corresponds more closely to the theoretical value for heat of adsorption for both solution and gel systems than it does for adsorption by nonswelling powders. [Bul. Pap. Chem. V. 28, No. 3]

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

FPRS News-Digest, Continued

NEW PRODUCTS—LITERATURE

New Mitre Saw Bench

A mitre saw bench that will cut a mitre and groove in one pass has recently been released by the Tannewitz Works. The machine comes with choice of 5 tables, tilting arbor saw with 5 hp totally enclosed fan-cooled motor, detachable stub arbors, and automatic guard.

It has a clamp nail groove cutting saw six inches in diameter that can be adjusted vertically as well as for depth of cut. The saw arbor runs in ball bearings and is driven through V-belts by a ½ hp motor connected to a manual control switch. Pushbutton control is also available. Complete details can be obtained from the Tannewitz Works, Grand Rapids, Mich.

New Machinery Brochure

A new 16-page brochure illustrating Washington Iron Works machinery installations in hardboard, particle board, and flakeboard plants has been released. Machinery in use in plywood, door, pulp baling, metal bonding and metal forming operations is also shown. Available by writing on company letterhead to Washington Iron Works, 1500 Sixth Avenue South, Seattle 4, Wash.

Log Cleaning Method

A log cleaning method has been announced by the Deming Co., Salem, Ohio. In the system, logs are soaked in a pond to soften the foreign matter on the bark. Removed from the soaking pit with a mechanical drag chain, the logs pass through a battery of high-pressure spray nozzles that forcibly remove foreign matter and loose bark. The water is pumped from the soaking pond by the Deming Fig. 4700 Vertical Turbine, and boosted to 175 pounds pressure for the spray heads. The water from the spray drains back into the soaking pond for eventual recirculation to the spray nozzles.

Removable Glue Pan

A new feature for the Black Bros. No. 2–8 inch glue spreader allows faster clean-up time, the firm announced recently. The change is a quickly removable glue pan that permits quick machine disassembly for more thorough cleaning, and eliminates unnecessary down time. More information is available from The Black Bros. Co., Inc., Mendota, Ill.

New Plywood Finish Developed

A new machine process that imparts a smooth, glossy, hard finish to any type of wood at a rate of 90 to 120 linear feet per minute, has been developed by Satin Surfaces, Inc., H. M. Reed, Jr., president of the firm, announced recently.

Called "Super Microseal", the patented technique uses pressure and friction to create heat which melts lignin in the wood's surface. This is blended with a synthetic resin developed for the process by Reichhold Chemical Co. Together, they form a dense, smooth, hard, water-spot-resistant surface about 1/24 inches deep.

The process is said to eliminate grain and fiber raising and variations in surface texture, while producing a surface far smoother than the most careful sanding. Hand sanding, sealer and second coatingsg are eliminated which means at least a 75 per cent reduction of the cost of finishing doors, furniture parts, cabinets, and so forth.

Stain can be introduced into the wood surface during the process, creating a final finish. Otherwise, the surface, which costs about one-half cent per square foot serves as a base for a single coat of paint, oil stain, or varnish. Satin Surfaces Inc., a wholly owned subsidiary of General Plywood Corp., developed the mechanics of the process, while Reichhold Chemicals Inc., developed the synthetic resin involved.

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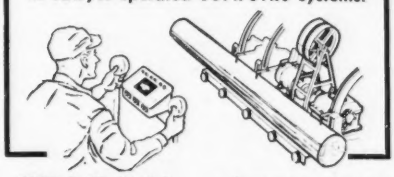

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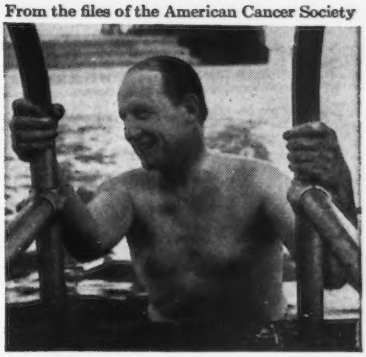

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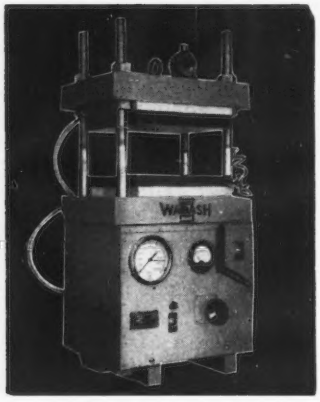

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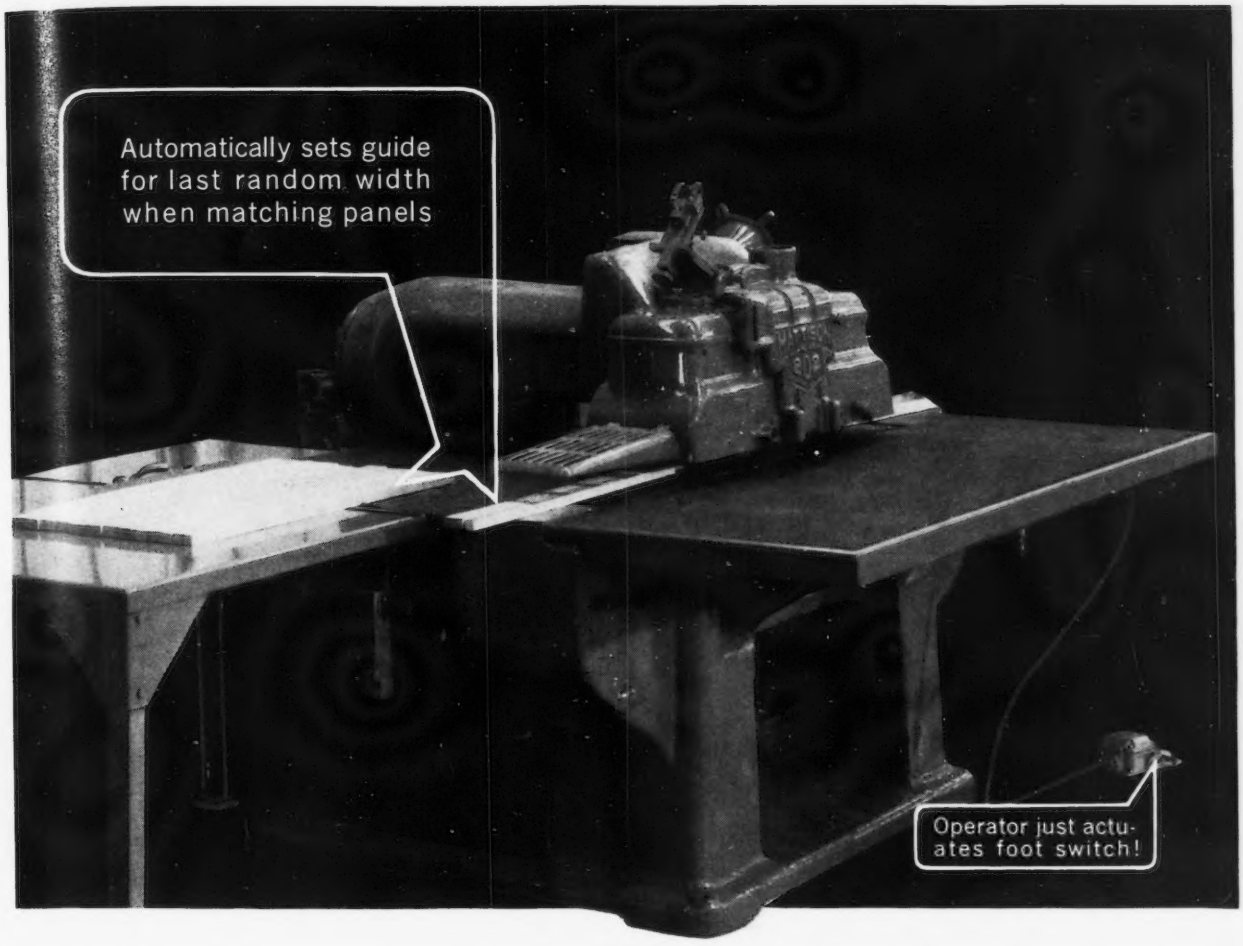

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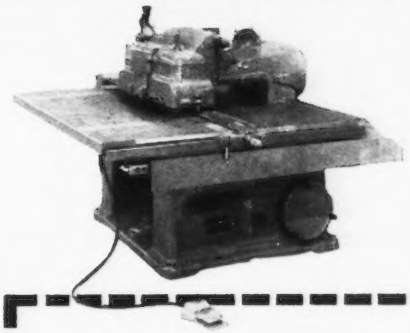

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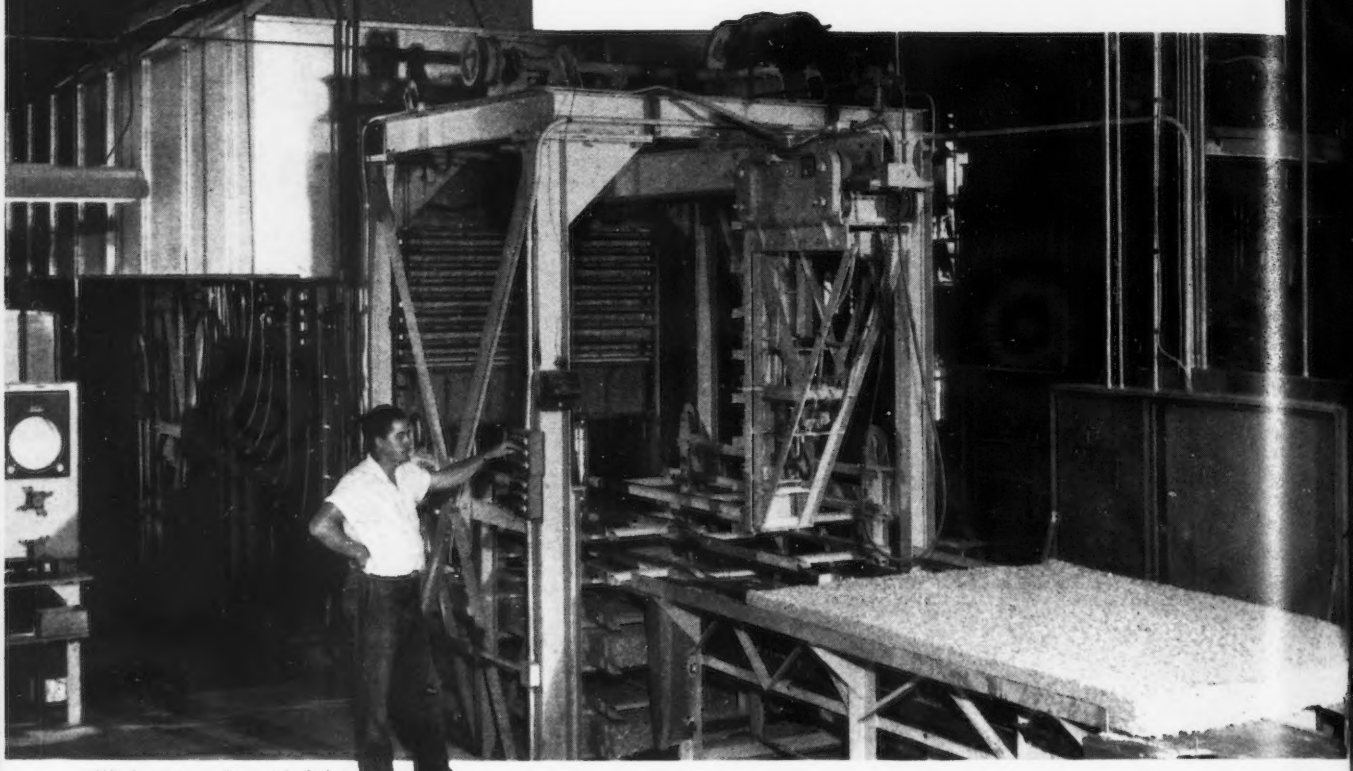
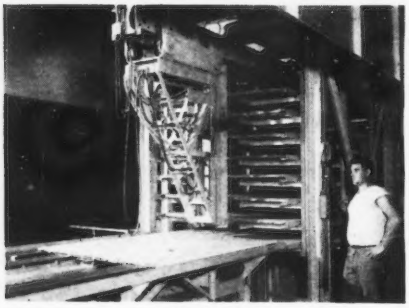


Washington equipment includes injector (with mat), loader, 1200-ton 8-opening press, unloader, ejector and controls. Below is the unloader and ejector removing finished flakeboard panels on completion of curing.



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PRODUCT: "Parflake" and "Tripleflake" FLAKEBOARD

There are good reasons why outstanding board producers, and the engineers responsible for the plants and processes, rely upon Washington presses and accessory equipment.

Performance is one reason, and a good example is the new flakeboard plant of American Parboard Corp., rated with a capacity of ten million square feet annually (¾″ basis). Currently, two 8-hour shifts daily produce 20,000 square feet. A Washington 8-opening hot press and companion loading and unloading equipment makes possible one-man control of the entire pressing stage.

Washington presses are custom designed and built to meet any requirement of platen size, board pressures and production rates. For complete information on presses, loaders and unloaders, conveyors and special machinery for automatic board production, write to Washington Iron Works, 1500 Sixth Avenue South, Seattle 4, Washington.

WASHINGTON presses and accessory equipment

HOT PLATE PRESSES • PULP BALING PRESSES • SPECIAL HYDRAULIC PRESSES • AUTOMATIC PRESS LOADERS AND UNLOADERS • COMPLETE DRY PROCESS HARDBOARD FORMING LINE EQUIPMENT

WASHINGTON IRON WORKS